

Note

Is there an error in
addition on page 4?

J. J.

HR-memo - see last # of Syllabus -

711C-30

PARTIAL REPORT
OF SURVEY ON
RUN-OFF AND WATERFLOW RETARDATION AND SOIL EROSION PREVENTION
FOR
ARROYO SECO WATERSHED
LOS ANGELES RIVER DRAINAGE

INTRODUCTION

Authority: This survey report is made in compliance with the Flood Control Act of June 22, 1936, Public No. 738 -- 74th Congress, as follows:

"Section 6 -- The Secretary of Agriculture is authorized and directed to cause preliminary examinations and surveys for run-off and waterflow retardation and soil erosion prevention on the watersheds of the Los Angeles, San Gabriel and Santa Ana Rivers of California."

PARTIAL REPORT

OF SURVEY OF

THE-ONE AND WATER-RESERVATION AND SOIL AND WATER RESERVATION

FOR

THE-ONE AND WATER-RESERVATION

THE-ONE AND WATER-RESERVATION

INTRODUCTION

Authority: This survey report is made in compliance with

the Flood Control Act of June 22, 1908, Public No. 733 -- 74th

Congress, as follows:

"Section 2 -- The Secretary of Agriculture is authorized

and directed to cause preliminary examinations and surveys for

run-off and waterflow retardation and soil erosion prevention on

the watershed of the Los Angeles, San Gabriel and Santa Ana

Rivers of California."

SYLLABUS

The Arroyo Seco watershed, a part of the Los Angeles River system, has been selected for this first detailed survey report on flood problems and remedial measures for Southern California. The report is designed to serve two purposes: (1) To form the basis of recommendations for immediate action in flood control measures; (2) To serve as a model or sample of the major detailed reports designed to cover the three major watersheds of the Los Angeles, San Gabriel, and Santa Ana rivers.

The Arroyo Seco is a watershed typical of the mountainous territory included in these three drainages. In itself it is a serious flood problem area, comprising the usual combination of high, rugged, fire-scarred terrain above heavily developed and rich municipal areas, expensive downstream flood control structures, and populations dependent upon water supplies derived from mountain watersheds. Fire and extensive road construction, naturally highly erosive slopes and torrential rainfall, have combined to create intolerable conditions of excessive runoff, slides and erosion that jeopardize extraordinarily high values downstream.

Remedial measures proposed are those applicable throughout the mountain territory and, in general, are typical as to relative costs and benefits. They are practical and economically sound methods of developing a continuing program of flood control which, after a period of some years, is expected to perform effectually the desired functions in abatement of the present heavy flood menace.

SYNOPSIS

The Arroyo Seco watershed, a part of the Los Angeles River system, has been selected for this first detailed survey report on flood problems and remedial measures for Southern California. The report is designed to serve two purposes: (1) To form the basis of recommendations for immediate action in flood control measures; (2) To serve as a model or sample of the major detailed reports designed to cover the three major watersheds of the Los Angeles San Gabriel, and Santa Ana rivers.

The Arroyo Seco is a watershed typical of the mountains territory included in these three drainages. In itself it is a serious flood problem area, comprising the usual combination of high, rugged, fire-scarred terrain above heavily developed and rich municipal areas, extensive downstream flood control structures, and population dependent upon water supplies derived from mountain watersheds. Fire and extensive road construction, naturally highly erosive slopes and torrential rainfall, have combined to create intolerable conditions of excessive runoff, slides and erosion that jeopardize extraordinarily high values downstream.

Remedial measures proposed are those applicable throughout the mountain territory and, in general, are typical as to relative costs and benefits. They are practical and economically sound methods of developing a continuing program of flood control which, after a period of some years, is expected to perform effectively the desired functions in abatement of the present heavy flood menace.

TABLE OF CONTENTS

	<u>Page</u>
I. SUMMARY	1
II. FACTUAL INFORMATION CONCERNING WATERSHED	3
III. FLOOD PROBLEMS AND REMEDIAL MEASURES	22
IV. PLAN OF IMPROVEMENT	25

PHOTOGRAPHS

Plate 1.	San gabriel Mountain Range	3a
2.	Channel Debris	5a
3.	Channel Scouring	5b
4.	Stream Channel Conditions	8a
5.	" " "	8b
6.	" " "	8c
7.	Devil's Gate Reservoir	18a
8.	Flood Damage in Arroyo Seco Canyon	19a
9.	" " " " " "	19b
10.	" " " " " "	19c
11.	Landslides	22a
12.	Highway Construction Scars	26a
13.	Highway Drainage Failure	26b
14.	Angeles Crest Highway	26c
15.	European Channel Control	27a
16.	Landslides	31a

TABLES

1.	Maximum Seasonal Rainfall	7
2.	Flood Flows	9
3.	Burned Areas	14
4.	Downstream Flood Damages	17
5.	Upstream Flood Damages	18

TABLE OF CONTENTS

1962

- I. SUMMARY 1
- II. VERTICAL INFORMATION CONTAINING MATERIALS 2
- III. FLOOD INFORMATION AND REMEDIAL MEASURES 12
- IV. PLAN OF IMPROVEMENTS 22

CONTENTS

22	San Gabriel Mountain Range	1.	Place
22	Channel Delta	2.	
22	Channel Bounding	3.	
22	Stream Channel Conditions	4.	
22	" "	5.	
22	" "	6.	
122	Devil's Gate Reservoir	7.	
122	Flood Damage in Arroyo Cano Canyon	8.	
122	" "	9.	
122	" "	10.	
122	Landslides	11.	
122	Highway Construction Areas	12.	
122	Highway Damage Factors	13.	
122	Angels Crest Highway	14.	
122	European Channel Control	15.	
122	Landslides	16.	

TABLE

7	San Gabriel Mountain Range	1.
9	Place	2.
12	Channel Bounding	3.
14	Stream Channel Conditions	4.
16	" "	5.

MAPS IN ARROYO SECO PARTIAL REPORT

<u>Map No.</u>	<u>Map</u>
17	Location Map
18	Stream Mileage and Sub-drainage
19	Geology
20	Profile Index Map
21	Master Profile
22	Isohyetals - 64 Year Normal
23	Maximum Rainfall Intensities
24	Isohyetals, Two Flood Producing Storms
25	Ground Water Basins
26	Cover Type
27	Fire History
28	○ Road Erosion Control
29	○ Channel Control
30	○ Typical Profile
31	○ Typical Stream Barriers
32	○ Typical Sills
33	○ Typical Training and Retaining Walls
34	○ Landslide Control
35	✓ Slope and Land Use
36	✓ Critical Area and Soils
37	✓ Engineering and Mechanical Treatment
38	○ Fire Protection Projects

MAPS IN ANEROYO BRIDGE PARTIAL REPORT

<u>Map No.</u>	<u>Map</u>
17	Location Map
18	Stream Mileage and Sub-drainage
19	Geology
20	Profile Index Map
21	Master Profile
22	Isopycetes - 64 Year Normal
23	Maximum Rainfall Intensities
24	Isopycetes, Two Flood Producing Storms
25	Ground Water Basins
26	Cover Type
27	Fire History
28	○ Road Erosion Control
29	○ Channel Control
30	○ Typical Profile
31	○ Typical Stream Barriers
32	○ Typical Sills
33	○ Typical Training and Retaining Walls
34	○ Landslide Control
35	✓ Slope and Land Use
36	✓ Critical Area and Soils
37	✓ Engineering and Mechanical Treatment
38	○ Fire Protection Projects

I. SUMMARY

A. Factual Information Concerning the Watershed. The Arroyo Seco watershed comprises 29.9 square miles of mountainous drainage in Los Angeles County a few miles north of the City of Pasadena, California. Geologically, the area has been formed by block faulting of large masses of metamorphosed sediments, schists and gneisses to form a much fractured, disintegrating rock mass. The intermittent streams rise in the steep headwaters and flow out through rugged canyons across an extensive detrital cone formed at the mouth of the Arroyo Seco by past flood flows. Tributary channel gradients vary from 10 to 67 percent.

Based on computed normals for a 60-year period, rainfall varies from 15 inches in valley to 31 inches at Mt. Wilson. Stream flow in the Arroyo Seco varies from a minimum of 81 second-feet or 4.9 second-feet per square mile to a maximum recorded rate of 11,400 second-feet or 695 second-feet per square mile. Since 1825, 17 known floods have occurred in this area.

Of the 19,000 acres in this watershed, 33 percent or 6,350 acres are privately owned, the remainder being national forest. The mesa and valley sections of the watershed are all privately owned and comprise all of the residential and agricultural land in the drainage.

B. Flood Problems of the Watershed and Application of Remedial Measures.

Principal sources of erosion and flood debris are:

A. General Information Concerning the Watershed. The Arroyo

is a watershed comprising 29.9 square miles of mountainous drainage in Los Angeles County a few miles north of the City of Pasadena, California. Geologically, the area has been formed by block faulting of large masses of metamorphosed sedimentary, volcanic and gneissic to form a much fractured, disintegrating rock mass. The intense tectonic rise in the steep mountains and flow out through rugged canyon areas an extensive debris cone formed at the mouth of the Arroyo basin by past flood flows. Tributary channels contribute water from 10 to 25 percent.

Based on computed normals for a 60-year period, rainfall

varies from 15 inches in valley to 31 inches at Mt. Wilson. Stream flow in the Arroyo basin varies from a minimum of 81 second-feet or 4.9 second-feet per square mile to a maximum recorded rate of 11,400 second-feet or 695 second-feet per square mile. Since 1885, 14 known floods have occurred in this area.

Of the 12,000 acres in this watershed, 25 percent or 3,000 acres are privately owned, the remainder being national forest. The main and valley sections of the watershed are all privately owned and comprise all of the residential and agricultural land in the drainage.

B. Flood Problems of the Watershed and Location of Remedial

Measures.

Principal sources of erosion and flood debris are:

1. Channel scouring
2. Sheet and gully erosion from burned and other denuded areas.
3. Land slides.
4. Road slope erosion on 58 miles of road.

Remedial measures recommended for the Arroyo Seco are as follows:

1. Protection of watershed cover from fire
2. Stabilization and planting of erosion sources.
3. Reestablishment of vegetative cover.
4. Stabilization of stream gradients and reduction of channel scouring by means of minor engineering works.
5. Soil conservation measures on cultivated lands.

C. Plan of Improvement

1. Road erosion control	\$ 200,000 -
2. Minor engineering works	
a. Channel clearing	2600
b. Stream bed barriers	236,800
c. Training or retaining walls	180,600 -
d. Channel realignment	20,000
TOTAL CHANNEL IMPROVEMENTS	440,000 -
3. Landslide control (planting, stabilization, etc.)	52,000
4. Soil conservation measures	120,000
5. Fire protection measures	160,000 -
6. Facilitating operations	140,000 -
7. Camp installation and operation	<u>80,000 -</u>
TOTAL COST OF ALL IMPROVEMENTS BASED ON FORCE ACCOUNT LABOR	\$1,192,000

1. Channel widening
 2. Erosion and gully erosion from lands and other damaged areas
 3. Land clearing
 4. Road slope erosion on SE side of road
- Remedial measures recommended for the above items are as follows:

1. Protection of watershed cover from fire
2. Stabilization and planting of erosion courses
3. Establishment of vegetative cover
4. Stabilization of stream gradients and reduction of channel scouring by means of minor engineering works
5. Soil conservation measures on eroded lands

C. Plan of Improvements

1. Road erosion control \$ 200,000
2. Minor engineering works

a. Channel clearing	\$200
b. Stream bed maintenance	\$2500
c. Graveling or paving	\$20000
d. Channel widening	\$2000

TOTAL CHANNEL IMPROVEMENTS \$22,000

3. Landslide control (planting, stabilizing, etc.)	\$2,000
4. Soil conservation measures	\$20,000
5. Fire protection measures	\$20,000
6. Stabilizing operations	\$10,000
7. Camp installation and operation	\$2,000
TOTAL COST OF ALL IMPROVEMENTS BASED ON THREE ACCOUNT ITEMS	\$1,132,000

Summary of total costs by other types of labor:

1. Force Account	\$1,192,000
2. Works Progress Administration, labor	1,090,900
3. Civilian Conservation Corps	1,265,170
4. Force Account and WPA	1,083,600
5. Force Account and CCC	1,246,830
6. Force Account, WPA and CCC	1,219,530

D. Cost of Deferred Development

1. Minor engineering works	\$3,900,000
2. Landslide control	100,000
3. Improvement planting	100,000
4. Drainage improvements on trails and firebreaks	<u>10,000</u>
TOTAL COST OF DEFERRED WORKS	\$4,110,000

II. FACTUAL INFORMATION CONCERNING WATERSHED

A. Description of Area

1. Location and Size. The Arroyo Seco watershed comprises 29.9 square miles (19,000 acres) of mountainous drainage in the San Gabriel Range in Los Angeles County a few miles north of the City of Pasadena, California. (See vicinity map, Plate 17)

The following streams and canyons comprise the principal drainage units: (See Plate 18)

Summary of total costs by other types of labor:

1. Force account	\$1,182,000
2. Work Progress Administration, labor	1,030,000
3. Civilian Conservation Corps	1,265,170
4. Force account and WPA	1,085,000
5. Force account and CCC	1,240,000
6. Force account, WPA and CCC	1,212,000

B. Cost of Patented Developments

1. Minor engineering works	\$2,000,000
2. Landslide control	100,000
3. Improvement planning	100,000
4. Drainage improvements on trails and firebreaks	10,000
TOTAL COST OF PATENTED WORKS	\$4,110,000

II. NATURAL INFORMATION COMMISSION ESTIMATES

A. Description of Area

1. Location and Size. The study area watershed comprises 50.9 square miles (13,000 acres) of mountainous drainage in the San Gabriel Range in Los Angeles County a few miles north of the City of Los Angeles, California. (See vicinity map, Plate 17)

The following elements and persons comprise the principal drainage units: (See Plate 18)

PLATE 1



The San Gabriel mountain range in the background includes the Arroyo Seco watershed at left. Cities of Pasadena and Altadena in foreground depend largely upon the water supplies from the Arroyo Seco. Protection and improvement of these chaparral covered watersheds are essential to the well-being of the valley towns and cities situated in the path of the floods originating in the mountainous areas.

	Length in miles	Drainage area in sq.mi.
Ladybug Canyon	1.3	.72
Cloudburst Canyon	1.2	.47
Colby Canyon	1.9	1.47
Little Bear Canyon	1.7	.94
Bear Canyon	3.5	2.62
Long or Camp Canyon	1.5	1.62
Slide Canyon	1.1	.63
Dark Canyon	1.7	1.22
Pine Canyon	1.3	.63
Fern Canyon	2.3	.97
Coon Canyon	1.0	.15
El Prieto Canyon	2.8	1.01
Millard Canyon	5.2	2.25
West Ravine	2.5	1.30
Could Canyon	3.2	1.61
Flint Wash	2.5	4.23
Main Arroyo Seco	14.8	7.53
	<u>80.2</u>	<u>29.87</u>

49.5

2. Geology. The Arroyo Seco, typical of the watersheds in the Los Angeles and San Gabriel drainages, has been formed by block-faulting of large masses of metamorphosed sediments, schists and gneisses, with intrusion of granites. This section has been uplifted and tilted as characterized by the steep slopes and deep canyons. An extensive detrital cone has been built up from the mouths of the front canyons and the Arroyo Seco extending from the 1000 ft. contour on an approximate gradient of 15 percent.

The great bulk of the watershed is formed by the San Gabriel formation, a complex mixture of rocks consisting largely of Rubio metadiorite, Placerita meta-sediments and old granite, with frequent intrusions of Wilson diorite and Lowe granodiorite. (See Plate 19). The whole formation has been greatly faulted to form a much fractured, deeply weathered formation, disintegrating and

unstable rock mass.

The approximate areas of the various formations are as follows:

San Gabriel formation	13.18 sq.mi
Lowe granodiorite	6.44 sq.mi
Wilson diorite	5.03 sq.mi
Rubio diorite and metadiorite	.24 sq.mi
Echo granite	.69 sq.mi
Alluvium	4.29 sq.mi

3. Stream Channel Characteristics. The main channel of the Arroyo Seco may be divided roughly into three major sectors. From its source near Red Box at an elevation of 4670 feet, it flows westerly for about three miles along a well defined fault line. (See Plate 19). In this sector the average gradient is nine percent, with gradients on tributaries ranging from 10 to 67 percent.

In the second sector the Arroyo flows southerly and westerly through a precipitous rock walled canyon for a distance of five miles, where it enters the third sector, a broad canyon below Oakwilde. From Oakwilde the stream flows in a general southerly direction to Devil's Gate Dam, a distance by stream course of about seven miles. Channel gradients in this sector vary from 1.9 to 3.2 percent. Plate 20 shows the tributaries surveyed; Plate 21 is a composite drawing of the gradients of these tributaries.

South of Oakwilde the channel is characterized by moderately deep and unstable gravel deposits and by detrital cones at the mouths of the tributary channels.

Obstructions occur in the main channel where riparian vegetation has encroached upon the stream-bed during years of low flow.

unstable rock mass.

The approximate areas of the various formations are as follows:

15.15 sq. mi.	San Gabriel Formation
8.44 sq. mi.	Lower gneissitic
3.08 sq. mi.	William district
1.34 sq. mi.	Mobile district and metamorphic
0.99 sq. mi.	Granite
4.35 sq. mi.	Aluminum

5. Stream Channel Characteristics. (The main channel)

of the Arroyo area may be divided roughly into three major sectors. From its source near Red Box at an elevation of 6870 feet, it flows westerly for about three miles along a well defined fault line.

(See Plate 15). In this sector the average gradient is also present, with gradients on tributaries ranging from 10 to 25 percent. In the second sector the Arroyo flows southerly and westerly

through a rougher rock which causes for a distance of five miles, there is across the third sector, a broad canyon below Gila. From Gila the stream flows in a general southerly direction to Devil's Gate Dam, a distance of stream course of about seven miles. Channel gradient in this sector varies from 1.5 to

2.5 percent. Plate 16 shows the tributaries surveyed; Plate 17 is a composite drawing of the gradients of these tributaries. South of Gila the channel is characterized by moderately

deep and unstable gravel deposits and by detailed cones at the mouths of the tributary channels.

Disturbances occur in the main channel about riparian vegetation has been washed upon the stream-bed during years of low flow.



Large alders, boulders and debris impede
high flows in upper Arroyo Seco near survey
station H - 65 + 60.



Large alders undercut by March 1938 flood now choke El Prieto channel 1/2 mile above canyon mouth. Uncontrolled flood flows have seriously undercut stream banks and scoured the channel in this canyon. Channel gradient 7 percent; cross section about 3 feet deep and 15 feet wide.

Alders growing in the stream-bed impede high flows and obstruct free movement of flood debris.

4. Soils.

a. Soil Characteristics. The immature soils formed by decomposition of the parent rock material are sandy and rocky and vary in depth from zero to two feet.

b. Erosion. The light granular soil mantle of the upper watershed is highly erosive when depleted of its protective covering of vegetation. Occasional outcrops of granite and meta-diorite form rocky talus slopes with normally low erosion rates, but high runoff coefficients. Local areas of waterborne sedimentary deposits occur throughout the drainage. The lower reaches of the foothills and canyons are characterized by extensive outwash fans of alluvial material normally susceptible to moderate erosion but readily gullied by peak flood flows.

B. Hydrology

1. Precipitation

a. The storms which affect the Arroyo Seco watershed are of two distinct classes and occur only in the winter months. The most common type of storm is the regular cyclonic disturbance originating near the Aleutian Islands and normally progressing southeastward to California. These are characterized by air masses of mild temperature and high moisture content.

The second type of storm originates off the Mexican coast

and occasionally reaches southern California, causing local precipitation of torrential intensity.

b. While snow may fall on the highest peaks of this watershed it is usually only a few inches deep, melts rapidly and consequently has little importance in the flood problem.

c. Records from 22 rainfall stations for a period ranging from 1 to 38 years indicate that seasonal precipitation has ranged from 6 to 34 inches near the mouth of the canyon and from 11 to 60 inches at the higher elevations. The maximum seasonal rainfall measured at some representative stations of longest record are given in Table 1. Plate 22 shows the 64-year normal seasonal precipitation in this watershed, as computed by the War Department. The 24-hour and 1-hour maxima rainfall for a frequency occurrence of once in 50 years are shown in Plate 23, prepared by the War Department.

Table 1

Maximum Seasonal Rainfall Recorded

Period	<u>Pasadena</u> Elevation	<u>Mouth of Arroyo Seco*</u> Elevation	<u>Mt. Wilson</u> Elevation
1891 - 1900	30.71	--	--
1900 - 1910	27.03	--	--
1910 - 1920	34.12	--	48.92
1920 - 1930	29.61	38.32	60.51
1930 - 1938	31.38	32.45	58.88

* Pasadena Chlorine plant.

Plate 24 is an isohyetal map, from the Los Angeles County Flood Control District, showing the precipitation on the Arroyo

and occasionally reaches southern California, causing local precipitation of torrential intensity.

b. While snow may fall on the highest peaks of this watershed it is usually only a few inches deep, melts rapidly and consequently has little importance in the flood problem.

c. Records from 25 rainfall stations for a period ranging from 1 to 25 years indicate that seasonal precipitation has ranged from 6 to 56 inches near the mouth of the canyon and from 11 to 80 inches at the higher elevations. The maximum seasonal rainfall measured at some representative stations of longest record are given in Table I. Plate 22 shows the 54-year normal seasonal precipitation in this watershed, as computed by the War Department. The 24-hour and 1-hour maximum rainfall for a frequency occurrence of once in 50 years are shown in Plate 23, prepared by the War Department.

Table I

Maximum Seasonal Rainfall Recorded

Period	Recorded Elevation	Month of Record Elevation	St. Elmo Elevation
1891 - 1899	39.71	--	--
1900 - 1910	47.03	--	--
1911 - 1920	54.12	--	48.92
1921 - 1930	53.61	22.22	50.31
1931 - 1938	51.22	42.45	52.55

* Records obtained from

Plate 22 is an isohyetal map, from the Los Angeles County Flood Control District, showing the precipitation on the maps

Seco watershed in two large storms of recent years.

2. Streamflow

a. Flood flows in this tributary prior to 1914 were not recorded, but it may be assumed that more or less severe floods occurred on the Arroyo Seco during the years large floods were recorded on other tributaries of the Los Angeles and San Gabriel rivers. Local authorities agree that major floods have occurred in this region in the years 1825, 1840, 1862, 1884, 1889 and 1938.

The Los Angeles County Flood Control District has estimated the magnitude of the "capital flood" expected on the Arroyo Seco to be 27,000 c.f.s. or a maximum 24-hour flow of 14,000 acre-feet. A "capital flood" is defined by the County Flood Control District as the runoff from a storm having a probable 50-year frequency combined with a probable 50-year rainfall intensity based on computed rates for 5-minute to 24-hour periods.

The March 2, 1938 storm produced a momentary peak flow of 11,400 c.f.s. and a 24-hour flow of 7,420 acre-feet at the mouth of the canyon (inflow into Devil's Gate Reservoir).

b. Total, average, and minimum flow, the discharge per square mile of watershed area, and runoff in inches of water depth are given in Table 2 for years of high flows from the upper portions of the watershed.



PLATE 4B



A - Partially destroyed wire and rock mat check dam in El Prieto Canyon after October 1934 storms.

B - Same structure after March 1938 storms completely demolished. Carefully designed and located channel barriers will stabilize the channel floor and reduce side slope undercutting when supplemented by revegetation of land slides and areas of depleted watershed cover.

RELEASE NOTICE

This picture may be used for
 illustrative purposes only on the condition
 that the following be given in full:

PHOTO BY C. J. KRAEMER
 CALIFORNIA FOREST SERVICE
 U. S. FOREST SERVICE

STATE

CHG-1570

A - Partially damaged area and rock not shown in B
 Three copies after October 1955 storm.

B - Same structure after March 1955 storm completely de-
 veloped. Unusually deepened and located channel for-
 eign will stabilize the channel floor and reduce the
 slope undercutting when augmented by revegetation of
 bank sides and areas of depleted watershed cover.



A - Check dams constructed in El Prieto Canyon prior to 1934, partially destroyed by debris flows during 1934 storms.

B - Same location after March 1938 storms. Wire-bound rock mats inadequate in design and construction. Flood flows have scoured channel, cut side slopes and undermined trees to obstruct flow.

CHG-1253

RELEASE NOTICE

This picture may be reproduced or used for
illustrative purposes only on condition that credit
be given to the source.

W. J. KRAEDEL

CALIFORNIA STATE & BANK EXCHANGE CO.
FOREIGN SERVICE

1-31 11:30 AM

PLATE 55

CHG-1573



A - Check dam constructed in El Trieto Canyon prior to
1954, partially destroyed by debris flows during 1954
season.

B - Same location after March 1958 storm. Five-pound rock
note indicates in design and construction. Flood flows
have eroded channel, cut side slopes and undermined
stream to upstream flow.



PLATE 6B



A - El Prieto Canyon near survey station L - 34 + 56 after October 1934 storms.

B - Same location after March 1938 storms. Uncontrolled flood flows scoured channel and seriously under-cut side slopes, resulting in numerous land slides obstructing the channel. Control of these channels by streambed barriers and stabilization of land slides is necessary before flood flows can be reduced in this watershed.

Table 2

U.S.F.S. Gaging Station "Arroyo Seco at Pasadena"**

FLOWS DURING YEARS OF HIGH FLOW

Season	:Mean annual: : runoff :second feet:	: Annual : runoff :acre feet:	: 24 hour : Discharge c.f.s.: Max. :	: Momentary : peak Min. :	: Yearly : runoff :c.f.s. :	:c.s.m.:	:Inches
1913-1914	45.5	33,000	3,590	0.2	5,630	343	37.8
1915-1916**				0.6	3,150	192	
1921-1922	35.1	25,400	1,020	0.2	2,800	170	29.09
1934-1935	12.5	9,010	480	0	2,000	122	10.31
1937-1938					8,500	506	

* Located at Forest Service warehouse about two miles above Devil's Gate Reservoir and under 16.4 sq.mi. of the Arroyo Seco watershed.

** Partial records.

c. The principal improvements affecting flood flows in the Arroyo Seco consist of a flood control reservoir at the canyon mouth and a lined flood channel from the dam to the junction with the Los Angeles River.

The Devil's Gate Dam was built in 1920 by the Los Angeles County Flood Control District for flood control and water conservation purposes. It is situated in the Arroyo Seco, just below the mouth of the canyon. The original capacity of the reservoir was 4,608 acre-feet. The capacity in April 1938 was 2,979 acre-feet, a loss of 1,629 acre-feet or approximately one-third the original capacity, in 18 years due to deposition of erosion debris.

At the present time the channel from the Devil's Gate Dam to the junction with the Los Angeles River is being improved and has been designed to carry a flood peak several times the largest of record.

In addition to the above, several small debris basins have been constructed for protection against local flood threats.

5. Ground Water. Although the surface flow of the Arroyo Seco is tributary to the Los Angeles River, most of its underflow moves southeasterly into the San Gabriel Valley. The groundwater province affected by the Arroyo Seco occupies the northwest corner of the San Gabriel Valley and is known as Raymond Hill basin. As shown on Plate 25, it consists of three sub-basins designated as Monk Hill, Pasadena and Santa Anita Basins, the latter being of minor importance in connection with the Arroyo Seco.

The ground-water basins of the San Gabriel Valley have been the subject of intensive study by Federal, State and local agencies for many years and systematic ground-water measurements have been taken by them. Following agricultural and industrial expansion, and during the period of unusually low rainfall, ground water lowered year by year. Since 1932, however, there has been some recovery. In the Monk Hill Basin the Casitas well of the City of Pasadena dropped 62 feet between the spring of 1923 and early in 1931, with a recovery of 18 feet in the following six years.

As the present flow the channel from the Devil's Gate Dam to the junction with the Los Angeles River is being improved and has been designed to carry a flood peak several times the largest of record.

In addition to the above, several small debris basins have been constructed for protection against local flood threats.

3. Ground Water. Although the surface flow of the

Arroyo Seco is tributary to the Los Angeles River, most of its water flows southwardly into the San Gabriel Valley. The ground-water reserves affected by the Arroyo Seco comprise the northern corner of the San Gabriel Valley and is known as Raymond Hill Basin. As shown on Plate 22, it consists of three sub-basins designated as North Hill, Lechuguilla and Santa Anita Basins, the latter being of minor importance in connection with the Arroyo Seco.

The ground-water basins of the San Gabriel Valley have been the subject of intensive study by Federal, State and local agencies for many years and systematic ground-water measurements have been taken by them. Following agricultural and industrial expansion and during the period of unusually low rainfall, ground water lowered year by year. Since 1932, however, there has been some recovery. In the North Hill Basin the greatest well of the City of Los Angeles dropped 52 feet between the spring of 1932 and early in 1931, with a recovery of 18 feet in the following six years.

Likewise, in the lower Pasadena Basin, the city's Ohio Street well dropped 117 feet between 1919 and 1934. Recovery has been nominal.

The increasing demand for water in the Pasadena Basin has necessitated the deepening of wells and finally importation of water from other areas. Importing water from the San Gabriel and Colorado Rivers alleviates the threat of water shortage occasioned by overdraft of the local supplies. The cost of transporting water from the San Gabriel and Colorado Rivers is much greater than the cost of pumping; also the quality of the Colorado River water is inferior to local supplies.

As the recharge of the Monk Hill Basin, and to a lesser extent the Pasadena Basin, depend mainly upon percolation from the Arroyo Seco above Devil's Gate Dam, the matter of storage in the Devil's Gate Reservoir is quite important to underground water. Since this reservoir has now lost about 35 percent of its original capacity by silting, it is apparent that the water must be drawn down to a low point after each storm in order to leave storage space for a flood runoff. Thus a smaller amount of water can be stored than formerly, with consequent reduction in percolation.

C. Occupancy and Economy

1. History of Watershed. Prior to 1892 the Arroyo Seco watershed was public domain, open to entry through the homestead and mining laws. Land use was limited to a few scattered homesteads and mines and to grazing of sheep on the lower foothills. It was in effect an isolated mountain country comparatively

likewise, in the lower Kansas Basin, the city's Ohio Street well dropped 117 feet between 1919 and 1924. Recovery has been minimal.

The increasing demand for water in the Kansas Basin has

necessitated the deepening of wells and finally importation of water from other areas. Importing water from the San Gabriel and Colorado Rivers alleviates the threat of water shortage occasioned by overdraft of the local supplies. The cost of transporting water from the San Gabriel and Colorado Rivers is much greater than the cost of pumping, also the quality of the Colorado River water is inferior to local supplies.

As the recharge of the Rock Hill Basin, and to a lesser extent the Kansas Basin, depend mainly upon percolation from the Arroyo Pecos above Devil's Gate Dam, the matter of storage in the Devil's Gate Reservoir is quite important in underground water. Since this reservoir has now lost about 55 percent of its original capacity by silting, it is apparent that the water must be drawn down to a low point after each storm in order to leave storage space for a flood runoff. Thus a smaller amount of water can be stored than formerly, with consequent reduction in percolation.

6. Geography and History

1. History of Waterholes. Prior to 1892 the Arroyo Pecos

waterhole was public domain, open to entry through the homestead and mining laws. Land was now limited to a few scattered homesteads and mines and to grazing of sheep on the lower foothills.

It was in effect an isolated mountain country comparatively

inaccessible to the people of the small cities of Los Angeles and Pasadena. About that time, however, the population began to increase rapidly, and during the following decades the growth of Los Angeles and its neighboring cities was phenomenal. This growth brought sharply into focus the complex water supply and flood control problems through (1) Overflow of population and development to the debris cones and other hazardous flood areas, thus interfering with natural flood ways and placing in the path of floods man-made improvements of high value, (2) Increasing demands for local water supply, (3) Pressure for recreational outlets in the nearby mountain territories, thereby greatly increasing man-made disturbances on the watershed.

The creation of these problems was recognized by both Federal and local agencies. The San Gabriel Timberland Reserve, now included within the Angeles and San Bernardino National Forests, was the first area to be set aside by President Harrison in 1892 for watershed protection. It comprised an area of 555,520 acres from the mouth of Pacoima Canyon on the west to Cajon Pass on the east.

The report of the Board of Engineers on flood control submitted to the Los Angeles County Board of Supervisors in 1914, and resulting in the creation of the Flood Control District, recognized the value of watershed improvement and protection:

"All waters that bring about destructive floods rise in National Forest Reserves, which occupy 1520 square miles

inaccessible to the people of the small cities of Los Angeles and Pasadena. About that time, however, the population began to increase rapidly, and during the following decades the growth of Los Angeles and its neighboring cities was phenomenal. This growth brought sharply into focus the essential water supply and flood control problems through (1) Overflow of population and development to the debris cones and other hazardous flood areas, thus interfering with natural flood ways and placing in the path of floods man-made improvements of high value, (2) Increasing demands for local water supply, (3) Pressure for recreational outlets in the nearby mountain territories, thereby greatly increasing man-made disturbances on the watershed.

The creation of these problems was recognized by both Federal and local agencies. The San Gabriel Floodplain Reserve, now included within the Angeles and San Bernardino National Forests, was the first area to be set aside by President Harrison in 1892 for watershed protection. It comprised an area of 335,580 acres from the mouth of Iceberg Canyon on the west to Cajon Pass on the east.

The report of the Board of Engineers on flood control submitted to the Los Angeles County Board of Supervisors in 1914, and resulting in the creation of the Flood Control District, recognized the value of watershed improvement and protection:

"All waters that bring about destructive floods rise in National Forest Reserve, which occupy 1300 square miles

of the total 4,067 square miles of Los Angeles County. The methods available for flood control are broadly separable into two general classes opposite in their action. First those which accelerate the discharge of the main streams, such as improvements and straightening of channels. Second, those which retard and regulate the flow of the tributaries into the main stream, such as dams, the spreading of waters, the planting and preservation of trees and especially of low growing brush and willows."

The establishment of a strong, well-financed County Forestry Department to supplement Federal effort, was further evidence of the local concern in flood control problems. Residential developments in the valley and the attendant increase in values jeopardized by floods warranted the construction of a flood control dam in 1920 at Devil's Gate.

2. Fire. The vegetation of the watersheds of southern California has been greatly altered by repeated fires. After each fire the destroyed vegetation is replaced by lower types that can exist on the degraded sites, until finally repeatedly burned lands are covered with a mixture of chamise and mixed chaparral. Reference to Plate 26, the vegetative cover type map of the Arroyo Seco, will show that most of the watershed is now reduced to this type. Although it still provides fair cover and stabilization of the steep, unstable slopes, it is extremely inflammable.

of the total 4,000 square miles of Los Angeles County.

The methods available for flood control are broadly
separable into two general classes opposite in their
action. First those which accelerate the discharge
of the main stream, such as improvements and straight-
ening of channels. Second, those which retard and regu-
late the flow of the tributaries into the main stream,
such as dams, the spreading of waters, the planting and
preservation of trees and especially of low growing
brush and willows."

The establishment of a strong, well-financed County Forestry
Department to supplement Federal efforts, was further evidence of
the local concern in flood control problems. Residential develop-
ments in the valley and the attendant increase in values jeopardized
by floods warranted the consideration of a flood control dam in
1930 at Boyle's Lake.

2. Floods. The vegetation of the watershed of northern
California has been greatly altered by repeated fires. After each
time the destroyed vegetation is replaced by lower types that can
exist on the damaged sites, until finally repeatedly burned lands
are covered with a mixture of shrubs and mixed chaparral. Before
and to Plate 22, the vegetative cover type map of the entire State,
will show that most of the watershed is now reduced to this type.
Although it still provides fair cover and stabilization of the
steep, unstable slopes, it is extremely inflammable.

The following table indicates the acreage burned since 1877 as shown on Plate 27. Fire history prior to 1877 is unknown.

Table 3

Area Burned in Arroyo Seco

Date of: fire	:	:	:	:	:	:	:	:	:	:	:
1878:	1896:	1898:	1922:	1923:	1930:	1933:	1934:	1935:	Total		
Acreage burned	1622	6499	381	57	423	23	206	3717	1965	14,893	
Returned once					194	23	107	2079	1478	3,881	
Returned twice								23	487	510	

Total area unburned since 1877 is 4,968 acres.

The effects of fire on such watersheds transform ordinary flood flows of water into disastrous flows of mud, debris and boulders, overwhelming and extremely destructive. Water runoff peaks are greatly increased and further magnified by bulking with debris. The visible effects of past fires are easily read in the Arroyo Seco in large debris deposits, slides, and the rapid silting of the Devil's Gate Reservoir.

The population of the lowlands has recognized fully for many years the absolute necessity of fire protection for the cover on adjacent mountain lands. Volunteer organizations have contributed largely of man and money in active fire fighting in the absence of organized, permanent control. After the organization of the national forests, they have continued to strive for adequate

The following table indicates the average burned since 1877 as shown on Plate IV. The history prior to 1877 is unknown.

Table 2

Average burned in Arroyo Seco

Year of fire	1877-1880	1881-1890	1891-1900	1901-1910	1911-1920	1921-1930	1931-1940	1941-1950	1951-1960	1961-1970	Total
Average burned	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
Number of acres	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
Number of times	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5

Total area burned since 1877 is 4,000 acres.

The effects of fire on such valuable forest resources are
 those of water, fire, disease, and, above all,
 drought, overgrazing and extremely destructive. Water runoff
 is greatly increased and further regulated by holding with
 debris. The visible effects of past fires are easily seen in the
 Arroyo Seco in large debris deposits, slides, and the rapid sil-
 ting of the Devil's Gate Reservoir.

The population of the islands has recognized fully for many
 years the absolute necessity of fire protection for the cover on
 adjacent mountain lands. Volunteer organizations have contributed
 largely of men and money in active fire fighting in the absence
 of organized, permanent control. After the organization of the
 National Forests, they have continued to strive for adequate

financing of the necessary measures. Increased facilities have reduced the acreage of major fires by half, but the area is far short of adequate protection.

Flood control in such territory must begin with fire protection; vegetative cover alone can prevent the overwhelming of downstream works with debris and enormous losses in damage to property and engineering developments.

A full protection plan for the Arroyo Seco has been developed and will appear in a subsequent portion of this report. Its adoption and execution can provide the fullest possible measure of insurance against destructive debris flows, and provide opportunity for the future reestablishment of better protective cover over the whole watershed.

3. Water Rights. All water rights in the Arroyo Seco are owned by the City of Pasadena. Riparian rights in Millard Canyon, tributary to Arroyo Seco, are owned by Lincoln Avenue Water Company. Adjudication of ground-water rights is now under way. Mr. C. W. Sopp, Manager of the Pasadena Water Department, has stated that the proposed upstream flood control measures will materially benefit the present water supply by the reduction in channel bedload.

4. Water Power Development. The intermittent character of the tributary streams and the low summer flows in the Arroyo Seco are not favorable for power development.

financing of the necessary measures. Increased facilities have been
thus the source of major flood by half, but the area is far short
of adequate protection.

Flood control in each territory must begin with the protec-
tion; vegetative cover alone can prevent the overwhelming of down-
stream works with debris and enormous losses in damage to property
and engineering developments.

A full protection plan for the Arroyo has been developed
and will appear in a subsequent portion of this report. The
adoption and execution can provide the fullest possible measure of
insurance against destructive debris flows, and provide opportunity
for the future reestablishment of better protective cover over the
whole watershed.

3. Water Rights. All water rights in the Arroyo have
are owned by the City of Pasadena. Riparian rights in Millard
Canyon, tributary to Arroyo Creek, are owned by Lincoln Avenue
Water Company. Allocation of ground-water rights is now under
way. Mr. C. W. Cogg, Manager of the Pasadena Water Department, has
stated that the proposed upstream flood control measures will
materially benefit the present water supply by the reduction in
channel bedload.

4. Water Power Development. The inherent character
of the tributary streams and the low summer flow in the Arroyo
has not been favorable for power development.

5. Population. The population of Los Angeles County has increased from 101,454 in 1890 to 2,208,492 in 1930, necessitating importation of water from Owens Valley and the Colorado River to supplement formerly adequate local supplies. Encroachment of this increasing population upon the old detrital cones at the foot of the mountain range has magnified the flood hazards proportionately.

6. Land Ownership. Of the approximately 19,000 acres in this watershed, 33 percent or 6,350 acres are privately owned, the remainder being national forest. The mesa and valley sections of the watershed are all privately owned and comprise all of the residential and agricultural lands in the area.

7. Land Management.

a. Management of land in farms. The limited agricultural land in the watershed is cultivated primarily for the growing of grapes, fruits and grain. Little irrigation is involved. No improved practices such as contour cultivation are in operation on the gently sloping cultivated lands.

b. Management of land not in farms. The area not in cultivation is rugged, steep, and covered with brush and trees. It is valuable primarily for watershed. Management of this area has been principally for protection of the watershed cover to maintain and improve the yield of usable water and decrease flood intensities. Of secondary importance is the management of certain local areas within the watershed for recreational use.

3. Population. The population of Los Angeles County

has increased from 101,434 in 1890 to 2,203,492 in 1930, necessi-

tating importation of water from Owens Valley and the Colorado

River to supplement formerly adequate local supplies. Development

of this increasing population upon the old settled areas at the

foot of the mountain range has magnified the local demands proper-

ly.

4. Land Ownership. Of the approximately 19,000 acres

in this watershed, 25 percent or 4,750 acres are privately owned,

the remainder being national forest. The mesa and valley sections

of the watershed are all privately owned and comprise all of the

residential and agricultural lands in the area.

5. Land Management.

a. Management of Land in Forest. The limited and

cultivated land in the watershed is cultivated primarily for the

production of grapes, citrus and grain. Little irrigation is involved.

No improved practices such as contour cultivation are in operation

on the gently sloping cultivated lands.

b. Management of Land Not in Forest. The area not in

cultivation is rugged, steep, and covered with brush and trees. It

is valuable primarily for watershed. Management of this area has

been principally for protection of the watershed cover to maintain

and improve the yield of usable water and decrease flood intensities.

Of secondary importance is the management of certain local areas

within the watershed for recreational use.

D. Flood Damage and Erosion Losses

1. Flood Damage. Prior to the construction of the Devil's Gate Dam, flood flows caused serious damage to property and lands in the valley areas subject to overflow from this stream. Since the construction of this dam in 1920 flood damage has been limited to the canyons and lower sloping valley floor above the reservoir except during periods of extreme high flow when flood waters overtop the spillway, cause considerable damage to the highly developed areas below the dam and contribute to the flood peaks of the Los Angeles River. The danger of downstream flood damage becomes more serious with each storm that deposits a silt and debris load in the reservoir and thus reduces flood storage capacity. Damages incurred along the Arroyo Seco below Devil's Gate Dam during the March 1938 flood, shown in Table 4, emphasize the need for upstream control to supplement and safeguard existing downstream flood control facilities.

Table 4

Damages below Devil's Gate Dam, March 1938*

	:Residential:		: Roads :		:		:
	: and :	Agri-	: and :	Rail-	:		:
Total	: business	:cultural:	bridges:	roads	:Utilities:	Other	
1,335,000	85,000	7,000	497,000	75,000	444,000	227,000	

* U.S.E.D. Report on Flood Damage in Los Angeles Engineering District from storm of February 27 to March 3, 1938.

a. Direct Watershed Flood Damages, principally March 1938.

I. Flood Damage. Prior to the construction of the Devil's

Gate Dam, flood flows caused serious damage to property and lands in the valley areas subject to overflow from this stream. Since the construction of this dam in 1930 flood damage has been limited to the canyon and lower valley floor above the reservoir except during periods of extreme high flow when flood waters overflow the spillway, cause considerable damage to the highly developed areas below the dam and contribute to the flood peaks at the Los Angeles River. The danger of downstream flood damage becomes more serious with each storm that deposits a lift and debris load in the reservoir and this increases flood waters rapidly. Damages incurred along the river have been below Devil's Gate Dam during the March 1938 flood, shown in Table 4, emphasize the need for upstream control to supplement and reinforce existing downstream flood control facilities.

Table 4

Estimated Flood Damage in Los Angeles Region, March 1938

Estimated Flood Damage in Los Angeles Region, March 1938			
Property	Land	Water	Total
1,385,000	25,000	7,000	1,417,000
444,000	44,000	287,000	775,000

* U.S.E.C. Report on Flood Damage in Los Angeles Region, March 1938. Based on report of February 27 to March 3, 1938.

a. Direct Estimated Flood Damage, Principally March

Table 5

Direct Watershed Damages

<u>Class</u>	<u>Estimated Monetary Damage</u>
Roads	\$ 170,000
Reservoirs	171,150
Diversion works	28,000
Improved property	<u>68,200</u>
TOTAL	437,350

Roads. An estimated 300,000 cubic yards of soil was deposited in tributary stream channels as the result of road slope erosion, side canyon washouts, and inadequate drainage structures. The cost of repairing this road damage will be about \$170,000, segregated as follows:

Highways	\$ 126,000*
Minor roads	<u>44,000</u>
TOTAL	170,000

* Total amount spent by State Division of Highways to repair March 1938 storm damage on 12.8 miles of the Angeles Crest Highway.

This cost includes only that amount necessary to return these roads to safe travel conditions. Provision for adequate drainage and protection of the eroding slopes is not included.

Reservoirs. The figure of \$171,150 represents the portion of the original investment of \$483,943 in the Devil's Gate Reservoir lost on account of debris deposition, a large part of

Table 2

Direct Material Expenses

Class	Estimated Monetary Damage
Roads	\$ 170,000
Restoration	171,150
Diversions with	30,000
Improved property	<u>55,000</u>
TOTAL	426,150

Roads. An estimated 300,000 cubic yards of soil was deposited in tributary stream channels as the result of road slope erosion, side canyon washouts, and inadequate drainage structures. The cost of repairing this road damage will be about \$170,000, categorized as follows:

Highways	\$ 125,000*
Minor roads	<u>45,000</u>
TOTAL	170,000

* Total amount spent by State Division of Highways to repair March 1958 storm damage on U.S. miles of the Angeles Crest Highway.

This cost includes only that amount necessary to return

these roads to safe travel conditions. Provision for adequate

drainage and protection of the eroding slopes is not included.

Restoration. The figure of \$171,150 represents the portion of the original investment of \$420,000 in the Devil's Gate Reservoir lost on account of debris deposition, a large part of



Sediments at head of Devil's Gate reservoir viewed from Gould Mesa ridge and looking downstream toward dam. Severe erosion and subsequent sedimentation of the reservoir began after the Brown Mt. fire of 1934, and was greatly increased by the intense storms of March 1938. Devil's Gate dam and San Rafael Hills in right background.

which occurred during the 1938 storm.

Diversion Works and Water Supplies. Increased silting of the reservoir and channels has reduced the rate of percolation into underground storage basins 50 percent. The rate of percolation in 1920 was 20 second feet; the rate in 1938 after the March storm was 10 second feet. Continued reduction is expected in the advent of subsequent debris flows. Diversion works constructed in the lower canyon to divert water for domestic use were destroyed by debris flows with a loss of \$28,000. e

Improved Property, 1938. Damage to summer homes and resorts in the watershed was estimated to be \$44,600. Improved campgrounds, valued at \$23,000 were also destroyed.

2. Erosion Losses

a. Direct erosion losses. Damages to the watershed caused by flood flows are of four classes, namely:

(1) Channel scouring is probably one of the greatest contributors to abnormal debris flows. Total volume of material eroded by scouring is undetermined due to lack of channel cross-sections prior to flood periods.

(2) Gully erosion on areas of depleted cover. No definite measurements are available for the March 1938 flood but experimental data obtained on the Arroyo Seco and other southern watersheds show that erosion rates of 160,000 cubic yards per square mile did occur on slopes recently denuded by fire.

which occurred during the 1933 season.

Diversion Works and Water Supplies.

of the reservoir and channels has reduced the rate of percolation into underground storage basins 50 percent. The rate of percolation in 1930 was 50 percent less; the rate in 1933 after the North store was 10 percent less. Continued reduction is expected in the future of subsequent debris flows. Diversion works constructed in the lower canyon to divert water for domestic use were destroyed by debris flows with a loss of \$25,000.

Improved Property, 1933. Damage to owner houses and

resorts in the watershed was estimated to be \$15,000. Improved campgrounds, valued at \$25,000 were also destroyed.

2. Erosion losses

a. Direct erosion losses. Damage to the watershed

caused by flood flows are of four classes, namely:

(1) Channel scouring is probably one of the

greatest contributors to abnormal debris flows. Total volume of material eroded by scouring is undetermined due to lack of channel cross-sections prior to flood periods.

(2) Gully erosion on areas of depleted cover.

No definite measurements are available for the March 1933 flood but experimental data obtained on the Arroyo Seco and other southern watersheds show that erosion rates of 150,000 cubic yards per square mile did occur on slopes recently denuded by fire.



Arroyo Seco Canyon after March 1938 flood. Figure in middle-ground indicates high-water line and depth of channel gouging at camp ground site. Road, bridge, and camp ground completely destroyed at this point.



PLATE 9B



- A - Junction of Arroyo Seco and Pine Canyon after October 1934 storms. Note debris deposit in shallow channel and dense growth of vegetation in main canyon.
- B - Destruction of trees and scouring of channel to depth of 4 feet in Arroyo Seco at same location as above after March 1938 storms. Cabin at right amply protected by well-founded rubble masonry wall.



PLATE 10B



A - Junction of Arroyo Seco and Pine Canyon after October 1934 storms, showing accumulation of debris in channel and dense growth of canyon-bottom vegetation.

B - Same cabin as shown in Plate A after March 1938 storms. Channel cut 6 to 10 feet and canyon-bottom vegetation destroyed in path of flood flow.

6-11-1938

NOTICE
 This photograph is loaned to you for
 your information only. It is not to be
 reproduced or used in any way without
 the express written consent of the
 Bureau of Land Management.
 B. J. KRAEBEL
 PHOTOGRAPHY
 1515 UNIVERSITY AVENUE, DENVER, CO.
 80202

PLATE 108

68

Plate

NOTICE
 This photograph is loaned to you for
 your information only. It is not to be
 reproduced or used in any way without
 the express written consent of the
 Bureau of Land Management.
 B. J. KRAEBEL
 PHOTOGRAPHY
 1515 UNIVERSITY AVENUE, DENVER, CO.
 80202

A - Location of Arroyo Seco and the Canyon below
 1938 survey, showing accumulation of debris in channel
 and some growth of canyon-bottom vegetation.

B - Same area as shown in Plate A after March 1938 survey.
 Channel cut to 10 feet and canyon-bottom vegetation
 destroyed in part at least.

(3) Landslides resulting from depleted cover and unstable slopes. The total volume of soil displaced in landslides is approximately 195,000 cubic yards, mostly due to the 1938 storm.

(4) Road slope erosion on the 58 miles or road in this watershed is estimated to be 300,000 cubic yards.

Summarized, the erosion losses from the three measurable sources during the March 1938 flood were as follows:

Highways	250,000	cubic yards		
Minor roads	50,000	"	"	
Landslides	<u>195,000</u>	"	"	
TOTAL	495,000	"	"	or
	15,500	"	"	per sq.mi.

E. Flood Control Projects of Other Agencies

The Los Angeles County Flood Control District constructed a regulatory dam in Devil's Gate in 1920 with a storage capacity of 4,608 acre-feet at an approximate cost of \$483,943. This dam functions as a flood control structure as well as a water conservation measure. Its effect on floods has been to reduce greatly the danger of flood damage to the land below the dam. This effect in the future will be measurably less because of the loss of effective storage capacity due to sedimentation. Since 1920 the capacity of the reservoir has been reduced over one-third. Reduction in the capacity of this reservoir makes it essential to provide adequate channel protection below the dam. If restoration and improvement

of the watershed is not undertaken, a point will be reached when the effectiveness of the dam as a regulatory structure will be lost.

The construction of a lined flood channel in the Arroyo Seco Wash below Devil's Gate Dam is now under way by the U.S. Engineers Corps.

III. FLOOD PROBLEMS OF THE WATERSHED AND APPLICATION OF REMEDIAL MEASURES

1. Flood Problems

Torrential storms are concentrated often in a few days of the winter months when the major portion of the whole annual rainfall may come in a few hours.

Steep, rugged topography characterizes the whole watershed. The upper reaches are largely semi-barren rock outcrops from which run-off rates are exceedingly high.

Faulting and intrusions have broken and tilted formations so that the entire area is in an extremely unstable condition, susceptible to slides and debris flows when any disturbance takes place.

Erosive soils are formed from the underlying rocks. Thin and raw, they cling to steep broken slopes and contribute to the general problem of instability.

Accumulated debris, the result of many years of burning and consequent accelerated erosion and slides, form talus and debris deposits at the feet of the slopes and in the streambeds. If uncontrolled, all this material must move to the reservoir.

Road Construction on the faces of steep slopes causes large erosion from cuts and fills, and induces the formation of many slides where slope support has been removed.

Fires of the past have caused the development of slides and barren areas, and have lowered the type of vegetation to that capable of support by the impoverished sites. Any future fires on the now present highly inflammable vegetation will cause enormous flood and

I. Flood Problems

Temporary floods are concentrated often in a few days of the winter months when the major portion of the whole annual rainfall may come in a few hours.

These, termed temporarily characterized the whole watershed. The upper reaches are largely semi-barren rock outcrops from which runoff rates are exceedingly high.

Leaving and intrusions have broken and tilted formations so that the entire area is in an extremely unstable condition, susceptible to slides and debris flows when any disturbance takes place.

Ground water is formed from the underlying rocks. This and rain, they often to steep broken slopes and contribute to the general problem of instability.

Accumulated debris, the result of many years of bombing and consequent associated erosion and slides, form talus and debris deposits at the foot of the slopes and in the streambeds. If uncontrolled, all this material must move to the reservoir.

Good construction on the basis of steep slopes causes large erosion from cuts and fills, and induces the formation of many slides where slope support has been removed.

Lines of the past have caused the development of slides and barren areas, and have lowered the type of vegetation to that capable of support by the impoverished soils. Any future lines on the now present highly inflammable vegetation will cause enormous flood and



Numerous land slides on steep slopes on four-year-old burn in Arroyo Seco. The depleted plant cover and shattered rock formation increase the instability of these steep slopes.

Protection against fire, and revegetation of landslides and fire-depleted slopes will be the necessary measures to reduce runoff and erosion from this watershed.

debris flows from freshly denuded areas and prevent or postpone normal improvement in vegetative cover.

All these factors combine to create dangerous and costly floods in the Arroyo Seco, typical of those recurring in southern California watersheds.

The general nature of the topography, geology, soils and vegetation render fire the most important single agency in contributing to high flood hazards. In 1933, a storm of 12 to 19 inches produced run-offs of less than 60 second feet per square mile from certain well forested slopes in the Arroyo Seco. In the adjacent Pickens Canyon; where precipitation rates were slightly lower, but slopes had been recently burned, the rate of runoff was 1440 second feet per square mile, accompanied by the enormous movement of 160,000 cubic yards of debris per square mile. In 1934, 3000 acres of Arroyo Seco watershed were burned, and similar local flood flows were observed during the ensuing winter.

Agricultural areas within the watershed make their contribution to the general flood problem. Their relative importance in this watershed is small in comparison with that of the mountain area.

2. Remedial measures. Fire must be kept out of the forest. Increased protection facilities to safeguard the vegetative cover now on the ground and permit the reestablishment of suitable cover on thin and denuded areas are primary requisites of any flood control plan. This measure will reduce soil movement and run-off rates throughout the headwaters country. Measures looking toward mechanical fixation

of stream channels and unstable slopes can be of only small avail without adequate protection of vegetative cover from fire.

Vegetation must be reestablished on denuded areas caused by slides, road construction, and fires. These measures should be carried forward concurrently with minor engineering works designed to stabilize slopes and stream channels. Clearly, uncontrolled slopes continue to slide or erode. When mechanically controlled at the base, and on the contours, opportunity is afforded for revegetation of the slope itself. The effectiveness of such treatment has been shown and measured on roads in the San Dimas Experimental Forest. Untreated road slopes contributed up to 900 cubic yards of eroded material per acre while the erosion from properly controlled slopes was negligible. Similar methods applied to landslides can be expected to attain complete stabilization of the majority and partial stabilization of most of them.

In stream channels, the construction of barriers, sills, and training walls is designed to eliminate channel scouring, movement of debris already accumulated, undercutting of slopes, and formation of slides from this cause. Stream velocities will be reduced where possible according to the profile of the stream.

On agricultural lands, standard improved methods of cultivation are proposed to ameliorate existing flood and erosion conditions.

None of these measures can, of themselves, reduce run-off and erosion rates to the required degree. Combined, and carried forward in a reasonably coordinated way, they can contribute enormous results

in stabilization of debris and soils, and reduction of run-off rates.

IV. PLAN OF IMPROVEMENT

A. Plan for immediate development. In the following plan for development, the applicability of the remedial measures proposed has been carefully studied on the ground.

Detailed Cost Estimates. Cost estimates of the proposed remedial measures are based on a sampling method of survey and the assumption of certain average conditions. An exception is the recommended road erosion control work which was determined by a complete survey of all roads in the watershed. Cost estimates are on a force account basis. Possible contributions by CCC and other emergency labor are discussed later.

Channel stabilization measures were based on a survey of 10 miles of channel and the unit costs of structures obtained from similar types of construction in this locality. Accurate cost data for any individual structure can be obtained only by a detailed survey of each site. The estimated cost of landslide control is based on a survey of 84 percent of the watershed, or a total of 540 slides, having an aggregate area of 36 acres. In order to segregate slides requiring immediate control measures from those on which treatment could be deferred the following schedule of priorities was established:

Priority #1 - Active slides, jeopardizing roads and residential areas, or seriously threatening large soil masses, tress, etc., particularly in canyon bottoms.

in establishment of debris and debris, and reduction of water level.

IV. PLAN OF IMPROVEMENT

a. Plan for immediate development. In the following plan for

development, the applicability of the remedial measures proposed has been carefully studied on the ground.

Detailed Cost Estimates. Cost estimates of the proposed

remedial measures are based on a sampling method of survey and the assumption of certain average conditions. An exception in the case of roaded road erosion control work which was determined by a complete survey of all roads in the watershed. Cost estimates are on a basis of needed funds. Possible contributions by CCC and other agencies labor are discussed later.

Channel stabilization measures were based on a survey of

10 miles of channel and the cost estimate of structures obtained from similar types of construction in this locality. Accurate cost data for any individual structure can be obtained only by a detailed survey of each site. The estimated cost of landslide control is based on a survey of 84 percent of the watershed, or a total of 540 miles, having an aggregate area of 25 acres. In order to segregate slides requiring immediate control measures from those on which treatment

could be deferred the following schedule of priorities was established:

Priority I - Active slides, jeopardizing roads and residential areas, or seriously threatening large well known towns, etc., particularly in canyon bottoms.

Priority #2 - Active - debris entering principal stream channel directly.

Priority #3 - Active - far removed from roads and residential areas.

Priority #4 - Old slides more or less stabilized.

For an immediate action program only priorities 1 and 2 will be considered.

1. Measures chargeable exclusively to flood control.

a. Road Erosion Control. The Arroyo Seco watershed contains 12.8 miles of highway and 45 miles of minor roads, along which slopes need to be stabilized and better drainage provided. See Plate 28.

The method of slope stabilization consists of (1) mechanical anchorage of the slope surface by a system of contour trenching and imbedded wattles and stakes in various combinations and spacings suited to local soil conditions; (2) the sowing of cereal grains or other fast growing annuals to obtain the soil binding benefit of this temporary vegetation, and finally (3) the planting of suitable trees and shrubs to establish a complete self-perpetuating cover of vegetation.

The drainage measures needed consist principally of paved spillways to conduct road surface run-off to stream channels or to other safe places of disposal. Costs are estimated as follows:

Angeles Crest Highway

Slope stabilization - 50 acres at \$1600	\$80,000
Improved drainage - 12 miles at \$3600	43,000

Minor Roads

Slope stabilization - 32 acres at \$1000	32,000
Improved drainage - 45 miles at \$1000	<u>45,000</u>

Total	\$200,000
-------	-----------

Priority 2 - Active - debris entering principal stream

Channel directly.

Priority 3 - Active - for removal from roads and residential

areas.

Priority 4 - Old slides more or less stabilized.

For an immediate action program only priorities 1 and 2 will be

considered.

I. Measures chargeable exclusively to flood control.

a. Road Erosion Control. The Army has estimated con-

struction 12.8 miles of highway and 4.5 miles of minor roads, along with

slides need to be stabilized and better drainage provided. The State has

The method of slope stabilization consists of (1) mechanical

anchorage of the slope surface by a system of concrete bracing and

imbedded walls and stakes in various combinations and spacings suited

to local soil conditions; (2) the covering of exposed surfaces or other land

erosion channels to obtain the soil binding benefits of this temporary

vegetation, and finally (3) the planting of suitable trees and shrubs

to establish a complete self-perpetuating cover of vegetation.

The basic measures needed consist principally of paved spill-

ways to conduct road surface run-off to stream channels or to other

safe places of disposal. Costs are estimated as follows:

San Jose Creek Highway

100,000	Slope stabilization - 3.5 miles at \$1000
45,000	Improved drainage - 1.5 miles at \$3000

Minor Roads

25,000	Slope stabilization - 2.5 miles at \$1000
45,000	Improved drainage - 1.5 miles at \$3000

100,000	Total
---------	-------



Inadequate drainage facilities on Angeles Crest Highway results in serious erosion, often necessitating reconstruction of sections of the road.

Severe construction scars on Angeles Crest Highway and few land slides typify north and east exposures of Arroyo Seco. Slopes 70 to 100 percent, covered largely by oak-chaparral with big cone spruce in canyons. (See description.)



Inadequate drainage facilities on Angeles Crest Highway results in serious erosion, often necessitating reconstruction of sections of the road.

Spillways and adequate drainage of surface runoff is recommended for this location to prevent recurrence of damage and sedimentation of channels tributary to Devil's Gate Reservoir.



Fill slopes on Angeles Crest Highway treated for erosion control with layers of brush embedded in the fill during construction and then covered with rice straw. These slopes withstood the March 1938 storms.

Toe walls are needed to stabilize fills similar to one at left. Fill slope at right has adequate temporary protection but now needs planting.

b. Stabilization of Stream Channels. Channel conditions are of such a nature that the project will require use of several types of minor engineering structures. (See Plates 29 and 30) Streambed barriers or sills will be necessary to reduce stream gradient and velocity, in order to minimize channel cutting and scouring and the transportation of detrital material. Retaining walls are planned where necessary to prevent further undercutting of banks. Training walls are needed to deflect the stream course away from erodible banks and slides. The general purpose of all these measures is to permit the channel to become stabilized and bank vegetation to reestablish itself.

A moderate amount of channel realignment is required. Channel clearing will be necessary in certain places to remove obstructions such as boulders and down timber.

Most of the foregoing measures will be required in all of the channels of the Arroyo Seco watershed. The lower 7.5 miles of the main stream, from a point near Oakwilde to the Devil's Gate Reservoir, has been selected for the initial work. In this portion of the stream the channel widths are greatest and the structures will be of moderately large size. The measures applicable to this section of the stream are discussed in detail as follows:

(1) Stream Barriers or Sills. At the present time the main Arroyo Seco channel and most of the tributary channels contain a considerable volume of debris, estimated to range from 2,000 to 220,000 cubic yards per mile of channel. The only way this detrital



Channel control barriers of combined dry and wet rubble masonry. Note how the walls are carried up into the side slopes, well above the maximum flood-flow line, and how the concave crest gathers the flow to the middle of the structure. Torrent of St. Julien de Maurienne, Savoie, France. August 21, 1923.

material can be stabilized in place and prevented from being carried downstream to Devil's Gate Reservoir in subsequent flood flows is through the use of structures such as barriers and sills or debris retaining reservoirs. Since sites for adequate debris storage and debris disposal in this area do not exist, there is left only the method of barriers and sills. Approximately 10 structures of this type will be required in the Arroyo Seco from Oakwilde to the mouth of the canyon.

The barriers will be of either arch or gravity section depending on the site and economical requirements. They are to be constructed of concrete, well-bonded rubble masonry, or of interlocking pre-cast concrete blocks. The material to be used will be dependent on economy of construction, and will be determined by local conditions at the time the action program is initiated. (See Plate 31) Barriers will not ordinarily be constructed to a height in excess of 15 feet above the streambed. All barriers will be adequately designed in accordance with well-established engineering practice. Structures will be designed and constructed to eliminate failure by undercutting or scouring during flood periods.

Sills will be used to maintain the existing stream gradient and to prevent further movement of detritus and scouring of the channel. Their function will not be to reduce gradient or velocity. These structures ordinarily will be constructed flush with the bottom of the stream and the abutments will be carried sufficiently high to prevent side sloughing and undercutting by high flows. Sills will be adequately designed and constructed of concrete, rubble masonry or

material can be stabilized in place and prevented from being carried downstream to lower levels in the reservoir in subsequent flood flows in through the use of structures such as barriers and walls or debris retaining reservoirs. Since sites for adequate debris storage and debris disposal in this area do not exist, there is left only the method of barriers and walls. Approximately 10 structures of this type will be required in the Knapo River from below to the mouth of the canyon.

The barriers will be of either rock or gravity concrete depending on the site and economical requirements. They are to be constructed of concrete, well-graded rubble masonry, or of interlocking pre-cast concrete blocks. The material to be used will be dependent on economy of construction, and will be determined by local conditions at the time the action program is initiated. (See Exhibit II) Barriers will not ordinarily be constructed to a height in excess of 12 feet above the streambed. All barriers will be adequately designed in accordance with well-established engineering practice. Structures will be designed and constructed to eliminate failure by overtopping or scouring during flood periods.

Walls will be used to maintain the existing stream gradient and to prevent further movement of debris and scouring of the channel. Their function will not be to reduce gradient or velocity. These structures ordinarily will be constructed flush with the bottom of the stream and the abutments will be treated sufficiently high to prevent side scouring and undercutting by high flows. Walls will be adequately designed and constructed of concrete, rubble masonry or

pre-cast concrete blocks, carried to bedrock wherever economically possible. (See Plate 32) Where wall foundations on bedrock are impractical from an economic standpoint, the structures will be carried deeply enough to prevent undercutting and will be capped on sheet piling which will be carried to bedrock. If the driving of the sheet piling to bedrock is not practical, it will be driven sufficiently deep to furnish an adequate foundation and to serve satisfactorily as a cut-off. All structures will be well anchored and founded so that there will be no possibility of loss of the structures through undercutting and scouring.

(2) Training and Retaining Walls. Training walls will be used primarily to guide or change the course of the stream channel to prevent the recurrence of channel changes during high flows and subsequent undercutting of side slopes by an uncontrolled channel. Retaining walls will be used wherever their use will protect the base of land slips against cutting by stream flows, and where side sloughing can be arrested without the necessity of a channel change. The present uncontrolled condition of the stream and the attendant side sloughing in specific instances indicates that approximately 5300 lineal feet of these structures will be necessary.

Training and retaining walls will be constructed of reinforced concrete, rubble masonry, interlocking pre-cast concrete blocks, or of well anchored sheet piling. In some places, it may be desirable to use steel or concrete cribbing. (See Plate 33) All structures will be carried to bedrock insofar as possible and will be constructed so that

present concrete blocks, carried to bedrock wherever economically possible. (See Note 33) There will be foundations on bedrock and in-
practical from an economic standpoint, the structures will be carried
deeply enough to prevent undercutting and will be capped on about
filling which will be carried to bedrock. If the driving of the sheet
piling to bedrock is not practical, it will be driven sufficiently
deep to furnish an adequate foundation and to serve satisfactorily as
a cut-off. All structures will be well anchored and founded so that
there will be no possibility of loss of the structure through under-
cutting and settling.

(12) Training and Retaining Walls. Training walls will
be used primarily to guide or change the course of the stream channel to
prevent the recurrence of channel changes during high flows and main-
tain a uniformity of side slopes by an unobstructed channel. Retaining
walls will be used wherever their use will protect the base of land
slopes against cutting by stream flows, and where side sloping can be
retained without the necessity of a channel change. The present un-
trified condition of the stream and the adjacent side sloping in
specific instances indicates that approximately 3000 linear feet of
these structures will be necessary.

Training and retaining walls will be constructed of reinforced
concrete, rubble masonry, interlocking pre-cast concrete blocks, or of
well anchored sheet piling. In some places, it may be desirable to use
steel or concrete cribbing. (See Note 33) All structures will be
carried to bedrock wherever economically possible and will be constructed so that

there will be no possibility of loss of structures through undercutting or faulty foundations.

(3) Channel clearing. Immediate action is required to clear the main and tributary channels in the Arroyo Seco drainage of obstructions brought down by recent floods and the natural riparian growth that deflects the stream from its channel to cause damage which could be prevented by their removal. This work will involve the removal of those trees immediately adjacent to or in the channel which offer temporary obstruction for debris carried in flood flows, particularly where this condition would result in damage, or additional debris. In addition to this work it is planned to improve channel conditions by the removal of flood deposited debris consisting largely of wreckage of summer home cabins, large trees, and occasional boulders which would interfere with the proper control of the channel. It will be necessary to remove those cabins or summer homes in danger of destruction or damage by future floods, and those which will come within the flow line because of the construction of barriers and sills. Costs of stream channel stabilization in the main Arroyo Seco channel from mouth of canyon to Oakwilde, 7.5 miles, is estimated as follows:

Channel barriers, 10 structures	\$236,800
Training and retaining walls, 5300 lineal feet	180,600
Channel clearing, 5 acres	1,000
Channel realignment, 1000 lineal feet	20,000
Cabin removal	<u>1,600</u>
Total cost	\$ 440,000

there will be no possibility of loss of structure through subsiding
or faulty foundations.

(3) Channel clearing. Immediate action is required to

clear the main and tributary channels in the Arroyo from obstructions of
vegetation brought down by recent floods and the natural riparian
growth that blocks the stream from its channel to cause damage which
could be prevented by their removal. This work will involve the removal
of these trees immediately adjacent to or in the channel which either
temporarily obstruction for debris carried in flood flows, particularly
where this condition would result in damage, or additional debris.
In addition to this work it is planned to improve channel conditions
by the removal of flood deposited debris consisting largely of wreckage
of houses, farm buildings, large trees, and occasional boulders which would
interfere with the proper control of the channel. It will be necessary
to remove these obstructions or remove houses in danger of destruction or dam-
age by future floods, and a case which will come within the flow line
because of the continuation of banks and dikes. Growth of stream
channel stabilization in the main Arroyo from channel from mouth of
canyon to Catarillas, 7.5 miles, is estimated as follows:

Channel clearing, 5 acres	1,000
Channel realignment, 1000 linear feet	20,000
Channel barrier, 10 structures	120,000
Training and retaining walls, 2500 linear feet	120,000
Total cost	\$410,000

c. Landslide control. Landslides in the Arroyo Seco watershed result from the following causes:

1. Disturbance of unstable geologic formations
2. Saturation of shallow soils on steep slopes
3. Undercutting of slopes by streams
4. Depletion of vegetation by fire.

Slides contributing the largest volumes of debris and directly influencing floods are those formed along streambanks by the undercutting of the steep slopes by flood waters. These areas have been given high priority and are considered for immediate attention. (See Plate 34) Correction and control of these slides must be through the combined efforts of mechanical stabilization and revegetation. Treatment involves the use of one of five methods or a combination of several, and the details of each method are submitted with the cost estimates.

The estimated cost of landslide control is based on the following five methods of control:

No. 1. Direct seeding, contour strips or seed spotting,	
cost per acre	\$200.
No. 2. Planting, root or stem cuttings, cost per acre	400.
No. 3 Planting, nursery stock, cost per acre	150.
No. 4. Mechanical stabilization and planting, cost	
per acre	5000.
No. 5. Diversion of drainage and partial planting,	
cost per acre	400.

c. Landslide control. Landslides in the above cases

are caused by the following causes:

1. Disturbance of unstable geologic formations
2. Saturation of shallow soils on steep slopes
3. Undercutting of slopes by streams
4. Depletion of vegetation by fire.

Slides constituting the largest volume of debris and directly interfering with the flow of traffic are those formed along streambanks by the undercutting of the steep slopes by flood waters. These areas have been given high priority and are considered for immediate attention. (See Table 3a) Correction and control of these slides must be through the combined efforts of mechanical stabilization and revegetation. Treatment involves the use of one or five methods or a combination of several, and the details of each method are outlined with the cost estimates.

The estimated cost of landslide control is based on the following five methods of control:

Five methods of control:	
No. 1. Direct seeding, contour strip or seed casting,	
cost per acre	\$200.
No. 2. Planting, rock or wood cribbing, cost per acre	600.
No. 3. Planting, concrete armor, cost per acre	180.
No. 4. Mechanical stabilization and planting, cost	
per acre	8000.
No. 5. Diversion of drainage and partial planting,	
cost per acre	400.



Land slide blocking Arroyo Seco road after March 1938 storm. Slide caused by road construction and stream under-cutting. Typical of No. 1 priority classification. Methods of control recommended:

Method #1. Contour strips of cereal grain and seed-spots of native species.

Method #2. Cuttings of Baccharis, Yerba Santa or willow planted over entire slide area.

Method #4. Construction of a toe wall at base of slide to give stability to the steep 98 percent slope.

Priority No. 1.

Sub-drainage	Total	Number slides	Acreage by Treatments				
	slide		1	2	3	4	5
	area		1	2	3	4	5
	Acres						
Dark Canyon	3.0	13	3.0	3.0	2.0	1.0	3.0
Fern Canyon	1.0	24	1.0	1.0	-	0.5	1.0
Millard Canyon	2.0	11	2.0	2.0	-	1.0	2.0
El Prieto Canyon	0.5	3			0.5		0.5
Pine Canyon	0.5	4	0.1	0.1	0.3		0.5
Other Canyons	5.0	39	5.0	5.0	-	2.0	5.0
TOTAL AREAS	12.0	94	11.1	11.1	2.8	4.5	12
ESTIMATED COST			\$2200	\$4400	\$750	\$22,800	\$4800

Priority No. 2

Sub-drainage	Total	Number slides	Acreage by Treatment				
	slide		1	2	3	4	5
	area		1	2	3	4	5
	Acres						
Dark Canyon	3.0	41	3.0	3.0	2.5	-	3.0
Fern Canyon	3.0	61	3.0	2.5	1.0	-	3.0
Colby Canyon	1.0	8	1.0	1.0	-	-	1.0
Millard Canyon	1.0	26	1.0	1.0	-	-	1.0
El Prieto Canyon	1.0	38	1.0	1.0	0.5	-	1.0
Pine Canyon	1.0	7	1.0	1.0	-	-	1.0
Other Canyons	4.0	68	4.0	4.0	4.0	-	4.0
TOTAL AREAS	14.0	269	14.0	13.0	8.0	-	14.0
ESTIMATED COST			\$2900	\$5200	\$1200	-	\$5700

Total Cost of Landslide Control

Priority 1	\$37,000
Priority 2	<u>15,000</u>
Total	\$ 52,000

d. Erosion control and conservation measures on agricultural and urban areas. Of the 6,350 acres of private land in the Arroyo Seco watershed, 810 acres are cultivated, 1,800 acres in urban and suburban developments and the remainder is steep brush covered land. (See Plate 35) The agricultural and urban areas contribute to the flood problem by increased erosion from the cultivated lands and high run-off rates from the impermeable urban areas. Easement for construction on these private lands may best be secured through the organization of a Soil Conservation District.

Agronomy and Conservation treatment

<u>Orchards</u>	156 acres, plant entire area to permanent cover crop and basin list.
<u>Vineyards</u>	502 acres, fall cultivation by basin listing and plant annual winter cover crop.
<u>Hay land</u>	97 acres, terrace, basin list and sow cereal cover crop on 57 acres; convert 40 acres to woodland or chaparral watershed cover.
<u>Mixed field crops, deciduous and citrus fruits</u>	24 acres, basin list and plant cover crop.
<u>Unoccupied suburban property.</u>	200 acres, basin list and sow to permanent cover crop.

In addition to the agronomic measures recommended the following structures will be required, to reduce run-off, control erosion and

conserve water:

5 earth fill dams to function as run-off retention or silt basins

17 stabilization dams to retard channel erosion.

12,300 feet of unlined drainage ditches.

8,500 feet of concrete lined drainage ditches.

6 acres of terracing.

The estimated costs on agricultural and urban areas are estimated as follows:

Erosion control and drainage structures

5 earth-fill dams, 34,000 cu.yds	\$34,000
17 stabilization dams	15,250
8500 ft. of lined drainage ditch	62,300
12,300 ft. of unlined drainage ditch	8,750
6 acres, terracing, at \$40 per acre	<u>240</u>
	120,540

e. Fire protection measures. As has been pointed out, effective fire control is a basic requirement for flood control. Without it the proposed upstream measures on the mountain area will be futile, and the value of downstream works already constructed and being constructed by the Flood Control District and by the Army Engineers will be lost.

The original reason for the creation of the Angeles National Forest was in order to provide fire protection to the brush covered mountains and achieve flood control and insure water supplies. These basic reasons are unchanged; flood control begins with fire protection. Other values accruing from maintenance of brush cover are of little

connective water:

3 cubic feet dam to function as run-off retention or all-
season

IV stabilization dam to extend channel erosion.

12,500 feet of aligned drainage ditch.

2,500 feet of concrete lined drainage ditch.

6 acres of terracing.

The estimated costs on agricultural and stock areas are esti-

mated as follows:

Estimated control and drainage structures

3 cubic feet dam, \$4,000 per year

IV stabilization dam

2500 ft. of lined drainage ditch

12,500 ft. of aligned drainage ditch

6 acres, terracing, at \$50 per acre

\$40

120,000

effective fire control is a basic requirement for flood control. With-

out it the proposed upstream measures on the mountain area will be the

and the value of downstream works already constructed and being constructed

by the Flood Control District and by the Army Engineers will be lost.

The original reason for the creation of the Angeles National

Forest was in order to provide fire protection to the timber covered

mountains and achieve flood control and insure water supplies. These

basic reasons are unchanged; flood control begins with fire protection.

Other values resulting from maintenance of hydro cover are of little

economic consequence and only a byproduct to the major purpose of management of this area.

Detailed technical studies have been made by the Forest Service to determine the ways and means of bringing fire control to the required effectiveness, and plans have been developed as a result of such studies. Part of these plans have already been carried out. Their completion, vital to the whole flood control program, requires immediate availability of funds as shown below.

The essence of fire protection on these watersheds is quick detection and attack. This requires first, full coverage of the area from lookouts, most of which are already established. During the fire season, guards must be stationed at strategic points. Fifteen additional fire suppression stations, locations for which have been determined, are required at a cost of \$25,000.

The second phase of adequate fire control, rapid communication, is partly covered by existing telephone lines. Additional requirements, totalling one mile, are required at a cost of \$500.

The rugged terrain and inaccessibility of a large part of the watershed make imperative the construction of truck roads and trails for transportation of men, equipment and materials to the scene of the fire. In addition to existing facilities, 18 miles of roads and two miles of trails are required, at a cost of \$120,500. Additional water facilities, located with respect to fire fighting requirements, are an essential part of the program. Five of these will cost \$14,500.

f. Facilitating operations. In order to gain access

economic consequences and only a hypothesis to the water impact of resource
management of this area.

Detailed technical studies have been made by the Forest Service
to determine the ways and means of bringing fire control to the necessary
effectiveness, and plans have been developed as a result of such studies.
Part of these plans have already been carried out. Their completion,
vital to the whole flood control program, requires immediate availability
of funds as shown below.

The essence of fire protection in these watersheds is quick
detection and attack. This requires first, full coverage of the area
from lookouts, most of which are already established. During the fire
season, guards must be stationed at strategic points. Fifteen additional
fire observation stations, locations for which have been determined, are
required at a cost of \$25,000.

The second phase of adequate fire control, rapid communication,
is partly covered by existing telephone lines. Additional requirements
totaling one mile, are required at a cost of \$500.

The rugged terrain and inaccessibility of a large part of the
watershed make imperative the construction of truck roads and trails for
transportation of men, equipment and materials to the scene of the fire.
In addition to existing facilities, 18 miles of roads and two miles of
trails are required, at a cost of \$120,000. Additional water facilities
located with respect to fire fighting requirements, are an essential
part of the program. Five of these will cost \$14,000.

1. Facilities operations. In order to gain access

for transportation of men and materials to areas on which engineering operations and revegetation are planned, it will be necessary to construct 20 miles of roads and five miles of trail at a total cost of \$140,000.

g. Camp installation and operation. Under the plan of force operation, a figure of \$60 per month has been used to cover the cost of camp installation and operation, at a total of \$80,000.

Summary of Cost Estimates of remedial measures proposed for the immediate program and applying exclusively to Flood Control.

a. Road erosion control	\$200,000
b. Channel stabilization	440,000
c. Landslide control	52,000
d. Soil conservation measures	120,000
e. Fire protection measures	160,000
f. Facilitating operations	140,000
g. Camp installations and operation	<u>80,000</u>
Total cost - Force account	\$ 1,192,000

for transportation of men and materials to areas on which engineering operations and revegetation are planned, it will be necessary to construct 50 miles of roads and five miles of trails at a total cost of \$140,000.

5. Camp installation and operation. Under the plan of forest operation, a figure of \$50 per month has been used to cover the cost of camp installation and operation, at a total of \$60,000.

Summary of Cost Estimates of remedial measures proposed for the immediate program and applying exclusively to flood control.

\$200,000	a. Road station control
400,000	b. Channel stabilization
50,000	c. Landslide control
150,000	d. Soil conservation measures
100,000	e. River protection measures
140,000	f. Facilitating operations
60,000	g. Camp installation and operation
\$1,120,000	Total cost - Forest work at

B. Labor requirements, CCC contributions etc. As indicated the above table was computed on a straight force account basis. It is anticipated that, during the execution of the proposed projects, variable amounts of relief labor and CCC labor will be available. Some tasks are most suited to accomplishment by CCC; some can be done by relief labor; some must be carried out by force account. It is obviously impossible to cover all possible combinations of the three types of labor that may be available. In the following tabulations, the major types of probable combinations and attendant costs are set forth.

C. Plan for deferred development.

1. Measures chargeable exclusively to Flood Control. The ultimate requirement for minor engineering work in the entire watershed tributary to the main channel comprising barriers and sills, training and retaining walls, channel alignment, and channel clearing is based on a detailed survey and estimate prepared for a typical tributary stream 3.3 miles in length. This typical channel represents an average condition of the tributary streams throughout the watershed and indicates an expenditure of approximately \$3,460,000 in addition to the \$440,000 required for immediate remedial measures.

A fair sampling indicates that approximately 1400 barriers will be required ultimately in stream channels tributary to the Arroyo Seco (for ultimate construction) in addition to those proposed for immediate construction. The cost of the individual barriers in the main channel varies from a minimum of \$11,580 to a maximum of \$44,000. The barriers

in the tributary channels will range in cost from \$4000 to \$100 depending on individual site conditions.

Landslides in priority classes 3 and 4 should be considered for ultimate control at an estimated cost of \$100,000.

Trails and firebreaks will require remedial measures in the form of adequate drainage to eliminate erosion resulting from concentrated surface runoff from the cleared areas. Estimated cost of correcting drainage on 45.7 miles of trail and 60.7 miles of firebreak will be approximately \$10,000.

Planting and sowing on areas of partially depleted cover will be deferred until the more urgently needed remedial measures have been done. This work will consist largely of establishing a supplementary ground cover to afford greater protection to sparsely vegetated slopes which now contribute excess surface runoff. Approximately 4000 acres are in need of this treatment at a total cost of \$100,000.

Total deferred cost estimates are as follows:

Channel control and improvement	
Channel barriers, approximately 1400	\$2,041,300
Training and retaining walls, 70,000 lineal feet	1,853,700
Channel clearing, 19 acres	<u>5,000</u>
Total channel structures	\$ 3,900,000
Landslides, 46 acres	100,000
Improvement planting, 4000 acres	100,000
Drainage improvements	<u>10,000</u>
Total cost, deferred development	\$4,110,000

In the tributary channels will range in cost from \$4000 to \$1000

depending on individual site conditions.

Landslides in priority channels 3 and 4 should be considered

for ultimate control as an estimated cost of \$100,000.

Drainage and floodways will require remedial measures in the

form of adequate drainage to eliminate erosion resulting from excessive

water surface runoff from the cleared areas. Estimated cost of

correcting drainage on 62.7 miles of trail and 30.7 miles of fire-

break will be approximately \$10,000.

Planting and seeding on areas of partially depleted cover will

be deferred until the more urgently needed remedial measures have been

done. This work will consist largely of establishing a supplementary

ground cover to afford greater protection to sparsely vegetated slopes

which now contribute excessive surface runoff. Approximately \$500 acres

are in need of this treatment at a total cost of \$100,000.

Total deferred cost estimates are as follows:

Channel control and improvement	
Channel barriers, approximately 1400	\$2,042,300
Training and retaining walls,	
70,000 linear feet	1,828,700
Channel clearing, 10 acres	2,000
Total channel structures	\$3,873,000
Landslides, 40 acres	100,000
Improvement planting, 4000 acres	100,000
Drainage improvements	10,000
Total cost, deferred development	\$4,113,000

FORCE ACCOUNT ESTIMATES

Project	Materials and Equipment	Man-days Supervision	Supervision Cost	Man-days Labor	Labor Costs	Total Cost
Road Erosion Control	\$ 20,000	2840	\$17,000	36,400	\$164,000	\$ 200,000
Minor Eng. Works	50,000	5040	40,000	78,400	360,000	440,000
Landslide Control	2,000	1120	8,000	8,960	40,000	52,000
Soil Cons. Measures	12,000	1120	8,000	21,840	95,000	120,000
Fire Protection	50,000	1120	8,000	22,400	100,000	160,000
Facilitating Oper.*	50,000	1120	8,000	17,920	60,000	140,000
Camp Inst. & Oper.*	10,000					60,000
Total	194,000	11,760	69,000	185,920	829,000	1,192,000

Total Cost - Force Account -	Materials	\$194,000
	Labor & Sup.	928,000
	Camp Operation	70,000
		<u>\$1,192,000</u>

*This item can be proportionately distributed to each major activity but has been segregated purposely to ascertain project cost estimates in greater detail.

WPA ESTIMATES

Project	: Materials : and : Equipment	: Man-days : Supervision	: Supervision : Cost*	: Man-days : Labor	: Labor : Costs**	: Total : Cost
Road Erosion Control	\$ 20,000	2240	\$12,600	36,400	\$148,000	\$ 180,600
Minor Eng. Works	50,000	5040	28,800	78,400	319,500	398,300
Landslide Control	2,000	1120	7,200	8,960	37,000	46,200
Soil Cons. Measures	12,000	1120	7,200	21,840	88,500	107,700
Fire Protection	50,000	1120	7,200	22,400	91,100	148,300
Facilitating Oper.	50,000	1120	7,200	17,920	72,600	129,800
Camp Inst. & Oper.	10,000					80,000
Total	194,000	11,760	70,200	185,920	756,700	1,090,900

*Basis: \$65 Month - 140 month

**Basis: Average of skilled and common labor \$65 per month

Total Cost - WPA -	Materials	\$194,000
	Labor & Sup.	826,900
	Camp Operation	70,000
		<u>\$1,090,900</u>

CCC ESTIMATES

Project	: Materials : and : Equipment	: Man-days : Supervision	: Supervision : Costs	: Man-days : Labor	: Labor : Costs	: Total : Cost
Road Erosion Control	\$ 20,000	2600	\$10,790	32,000	\$215,800	\$ 246,590
Minor Eng. Works	50,000	3200	21,580	104,000	431,600	503,180
Landslide Control	2,000	2600	10,790	13,000	53,950	66,740
Soil Cons. Measures	12,000	1040	4,320	26,000	107,900	124,220
Fire Protection	50,000	1040	4,320	26,000	107,900	162,220
Facilitating Oper.	50,000	1040	4,320	26,000	107,900	162,220
Total	184,000	13,520	56,120	247,000	1,025,050	1,285,170

Total Cost - CCC - Materials \$184,000
 Labor & Sup. 1,025,170
 \$1,285,170

FORCE ACCOUNT AND WPA

Project	Material :		Force Account :		WPA	
	: Equipment:	: Man-days :	: Cost :	: Man-days :	: Cost	
Road Erosion Cont.	\$ 20,000			38,640	\$160,600	
Minor Eng. Works	50,000	5200	\$41,600	78,400	319,500	
Landslide Control	2,000			8,320	44,200	
Soil Cons. Measures	12,000	1200	9,600	8,960	37,000	
Fire Protection	50,000	1000	8,000	22,400	91,100	
Facilitating Oper.	50,000	5000	40,000	17,000	68,000	
Camp Inst. & Oper.	10,000	8750	70,000			
Total	194,000	21,150	169,200	173,720	720,400	

Force Account and WPA -	Materials	\$194,000
	Labor & Sup.	819,600
	Camp Oper.	70,000
		<u>\$1,083,600</u>

FORCE ACCOUNT AND CCC

Project	Material :		Force Account :		CCC	
	: Equipment:	: Man-days :	: Cost :	: Man-days :	: Cost	
Road Erosion Cont.	\$ 20,000			54,600	\$226,590	
Minor Eng. Works	50,000	5200	\$41,600	100,000	415,000	
Landslide Control	2,000			15,600	64,740	
Soil Cons. Measures	12,000	1200	9,600	20,000	83,000	
Fire Protection	50,000	1000	8,000	22,000	91,300	
Facilitating Oper.	50,000	5000	40,000	20,000	83,000	
Total	184,000	12,400	99,200	232,200	963,630	

Force Account and CCC -	Materials	\$184,000
	Labor & Sup.	1,062,830
		<u>\$1,246,830</u>

FOUR ACCOUNT AND TWO

Project	Material	and	Four account	Cost	Cost
Good Brown Coat	20,000		20,000	20,000	20,000
Minor Bag. work	20,000		20,000	20,000	20,000
Landfill Control	2,000		2,000	2,000	2,000
Soil Core. Material	12,000		12,000	12,000	12,000
Fire Protection	20,000		20,000	20,000	20,000
Refrigerating Equip.	20,000		20,000	20,000	20,000
Comp. Inst. & Equip.	10,000		10,000	10,000	10,000
Total	104,000		104,000	104,000	104,000

Four account and two -
 Material 104,000
 Labor & Bag. 20,000
 Equip. 20,000
 144,000

FOUR ACCOUNT AND TWO

Project	Material	and	Four account	Cost	Cost
Good Brown Coat	20,000		20,000	20,000	20,000
Minor Bag. work	20,000		20,000	20,000	20,000
Landfill Control	2,000		2,000	2,000	2,000
Soil Core. Material	12,000		12,000	12,000	12,000
Fire Protection	20,000		20,000	20,000	20,000
Refrigerating Equip.	20,000		20,000	20,000	20,000
Total	104,000		104,000	104,000	104,000

Four account and two -
 Material 104,000
 Labor & Bag. 20,000
 Equip. 20,000
 144,000

FORCE ACCOUNT, WPA AND CCC

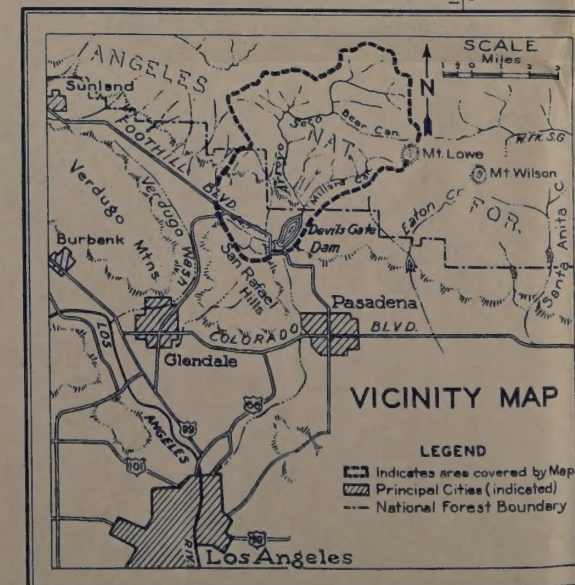
Project	: Materials :				: and : Force Account :				: WPA :				: CCC :			
	: Equipment :				: Man-days :				: Cost :				: Man-days :			
	: Cost :				: Man-days :				: Cost :				: Man-days :			
Road Erosion Control	\$ 20,000												54,000		\$226,590	
Minor Eng. Works	50,000	5200	\$41,600		35,000		\$140,000		50,000		\$07,500					
Landslide Control	2,000												15,000		64,740	
Soil Cons. Measures	12,000	1200	9,600		10,000		40,000		10,000		41,500					
Fire Protection	50,000	1000	8,000		12,000		48,000		10,000		41,500					
Facilitating Oper.	50,000	5000	40,000		10,000		40,000		10,000		41,500					
Camp Inst. & Oper.	5,000	5000	40,000													
Total	189,000	17,400	139,200		67,000		268,000		150,000		623,330					

Force Account, WPA and CCC -	Materials	\$189,000
	Labor	
	Force Acct.	139,200
	WPA	268,000
	CCC	623,330
	Total	\$1,210,530

ARROYO SECO WATERSHED

LEGEND

-  Watershed Boundary
 Sub Drainage Area Boundary
1.3 " " " (sq. miles)
 **2.5** Mileage of streams above indicated points



Project No. 155 Map No. 18
Source of Data U.S.G.S. Maps
Compiled by U.S.F.S. Date June 1938
Bureau U.S.F.S.
Approved *E. I. Ketchum* Bureau U.S.F.S.

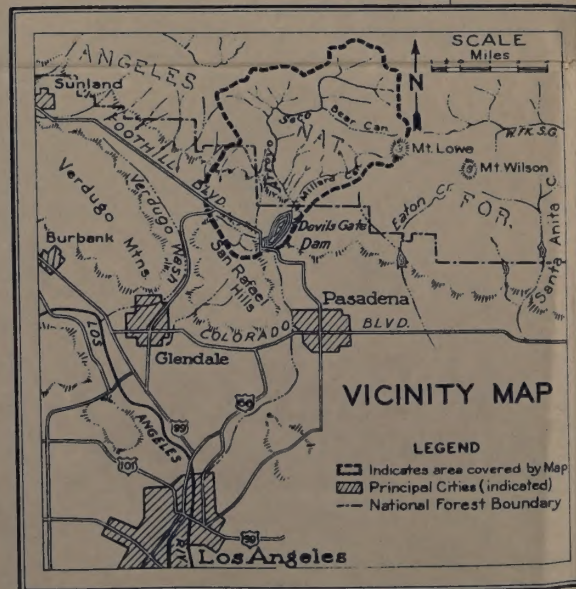
LOS ANGELES RIVER & TRIBUTARIES No. 155

ARROYO SECO WATERSHED

CHANNEL CONTROL MAP



- LEGEND**
- Watershed Boundary
 - Channel Barriers
 - Training Walls
 - Channel Clearing
 - Channel Realignment

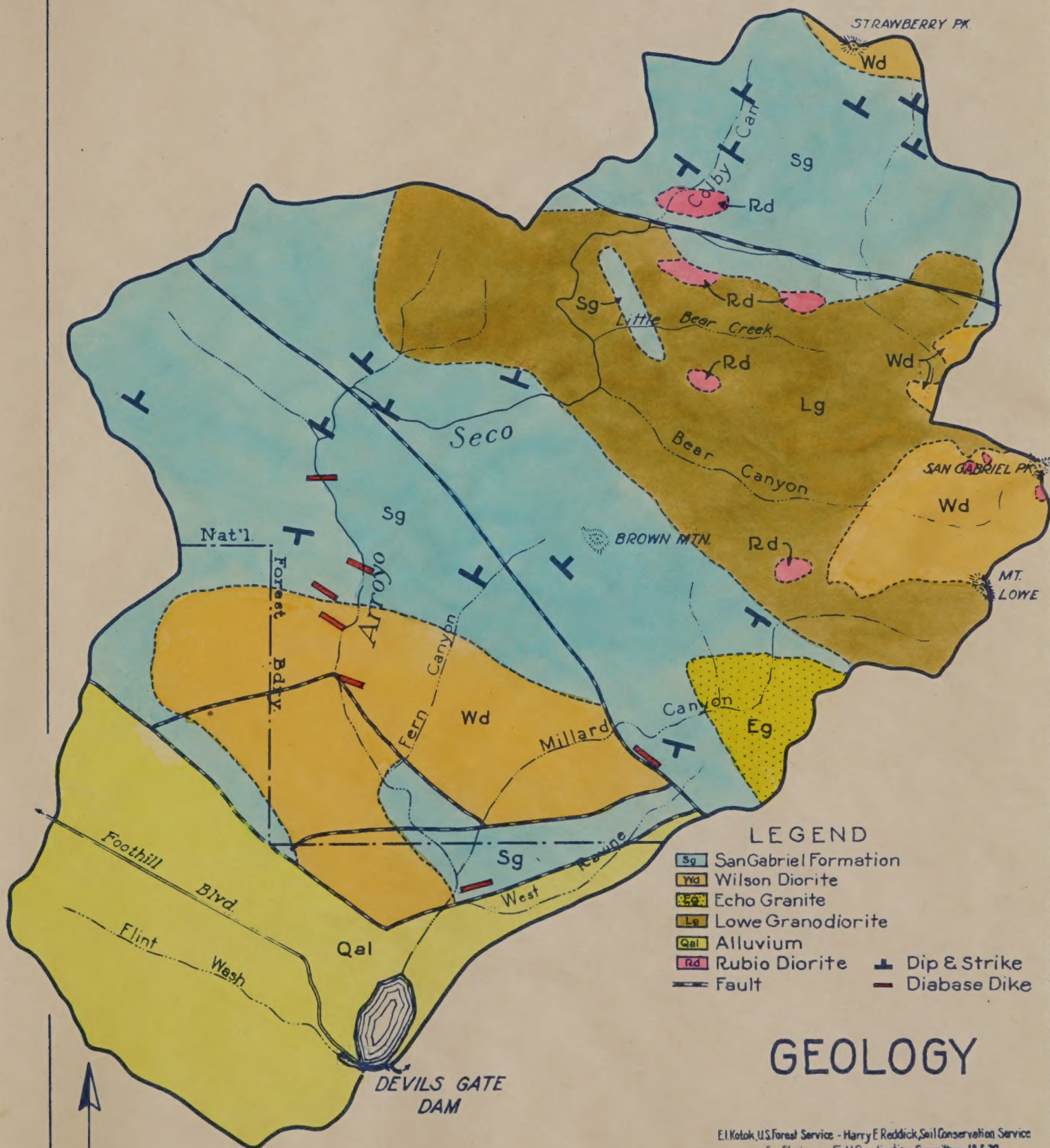


U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738

Project No. 155 Map No. 29
Source of Data Field Survey - U.S.F.S.
Compiled by U.S.F.S. Date June 1938
Bureau U.S.F.S.
Approved *E. I. Ketchum* Bureau U.S.F.S.

LOS ANGELES RIVER & TRIBUTARIES No. 155

ARROYO SECO WATERSHED



LEGEND

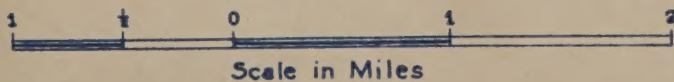
- | | |
|---|--|
| Sg San Gabriel Formation | T Dip & Strike |
| Wd Wilson Diorite | Diabase Dike |
| Eg Echo Granite | |
| Lg Lowe Granodiorite | |
| Qal Alluvium | |
| Rd Rubio Diorite | |
| Fault | |

GEOLOGY

E.I. Kotok, U.S. Forest Service - Harry E. Reddick, Soil Conservation Service
Co-Chairmen, Field Coordinating Committees 18 & 20

U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738

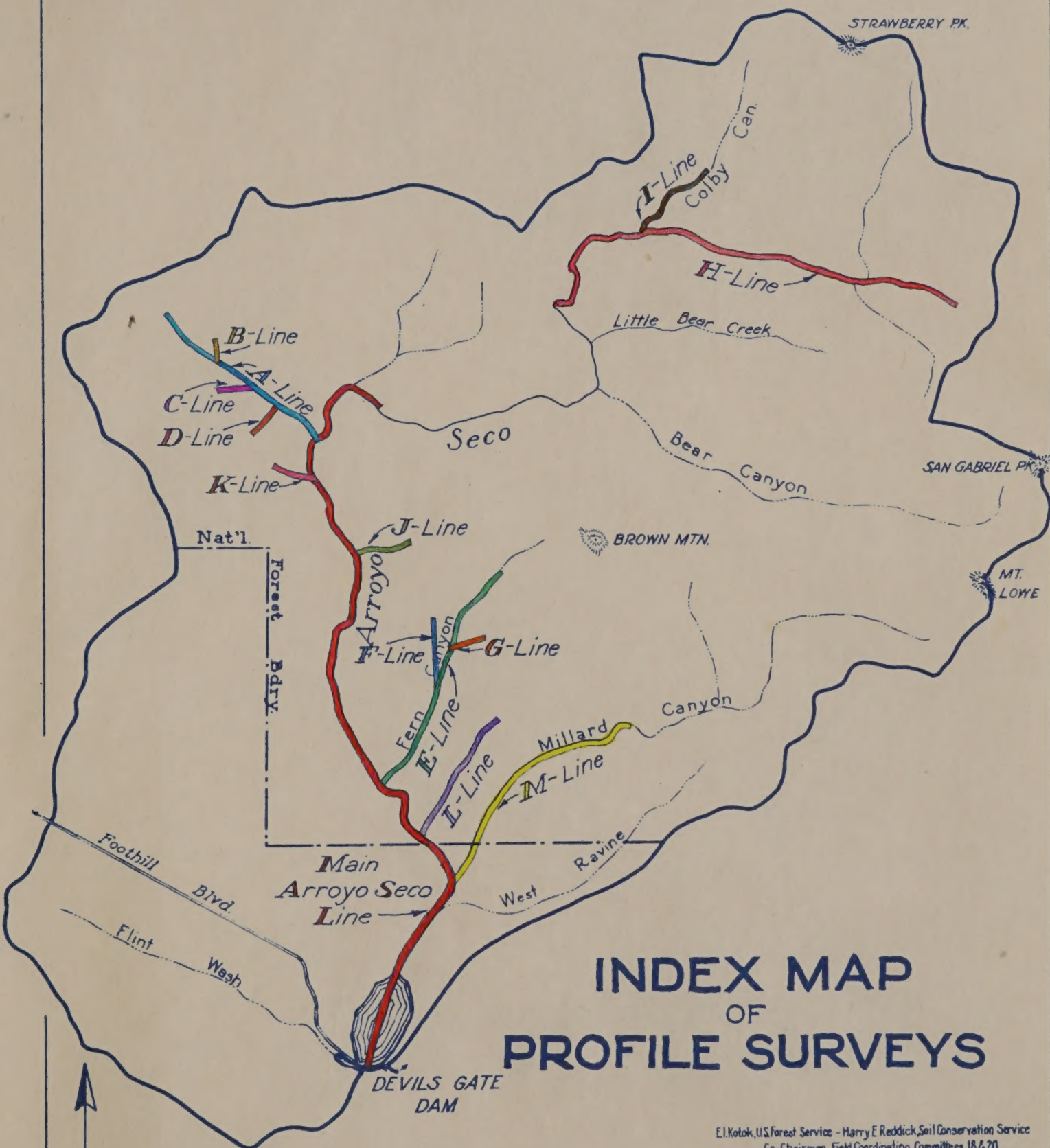
Project No. 155 Map No. 19
Source of Data University of Calif.
Compiled by U.S.F.S. Date 7/29/38
Bureau U.S.F.S.
Approved *E.I. Kotok* Bureau U.S.F.S.
AWL



BASE-U.S.G.S. 1:62,500 SCALE

LOS ANGELES RIVER & TRIBUTARIES No. 155

ARROYO SECO WATERSHED



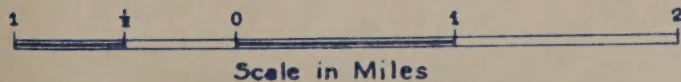
INDEX MAP OF PROFILE SURVEYS

E.I. Kotok, U.S. Forest Service - Harry E. Reddick, Soil Conservation Service
Co-Chairmen, Field Coordinating Committees 18 & 20

U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738

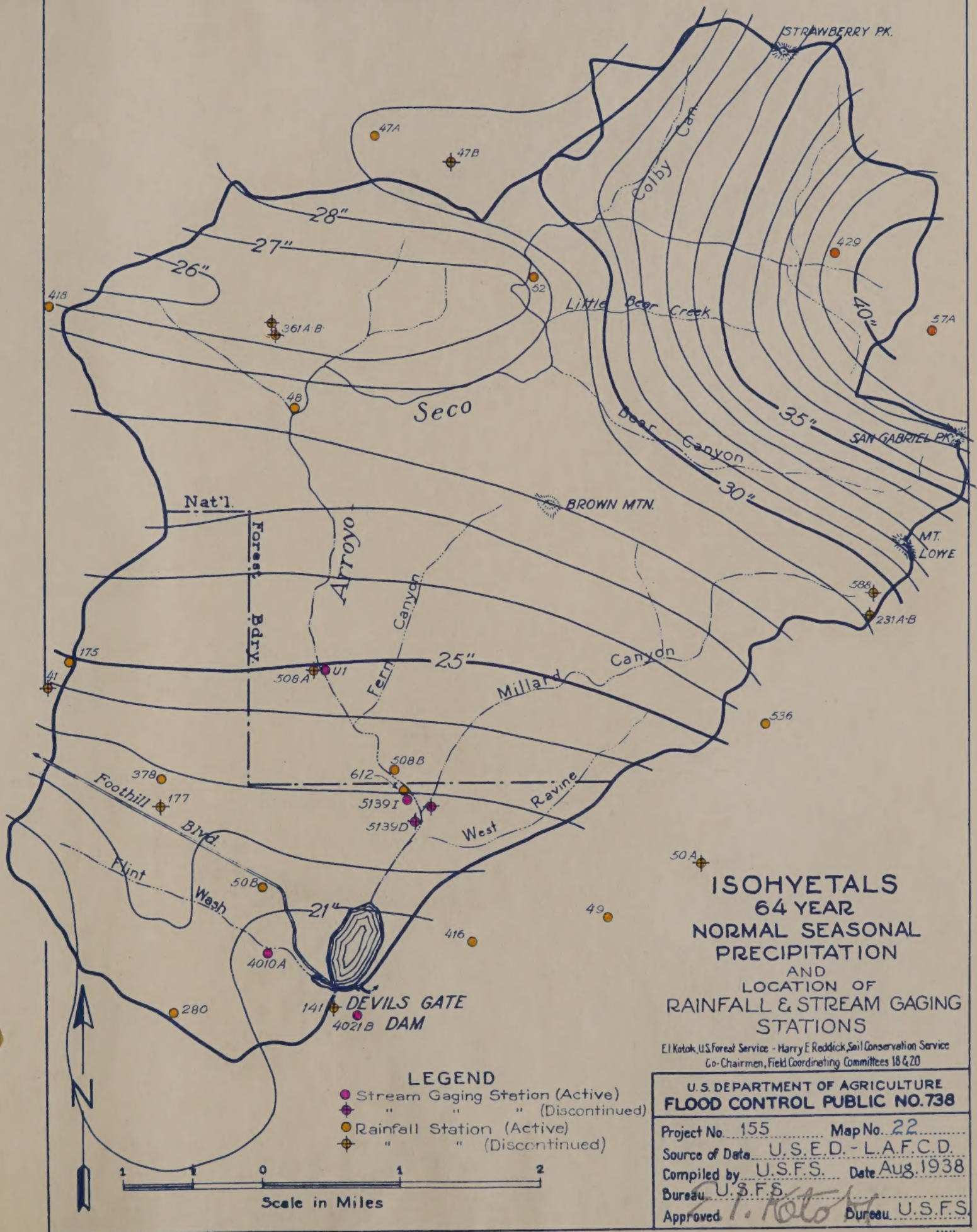
Project No. U.S.F.S. Map No. 20
Source of Data U.S.F.S. Field Survey
Compiled by U.S.F.S. Date Aug. 1938
Bureau U.S.F.S.
Approved *E.I. Kotok* Bureau U.S.F.S.

AWL



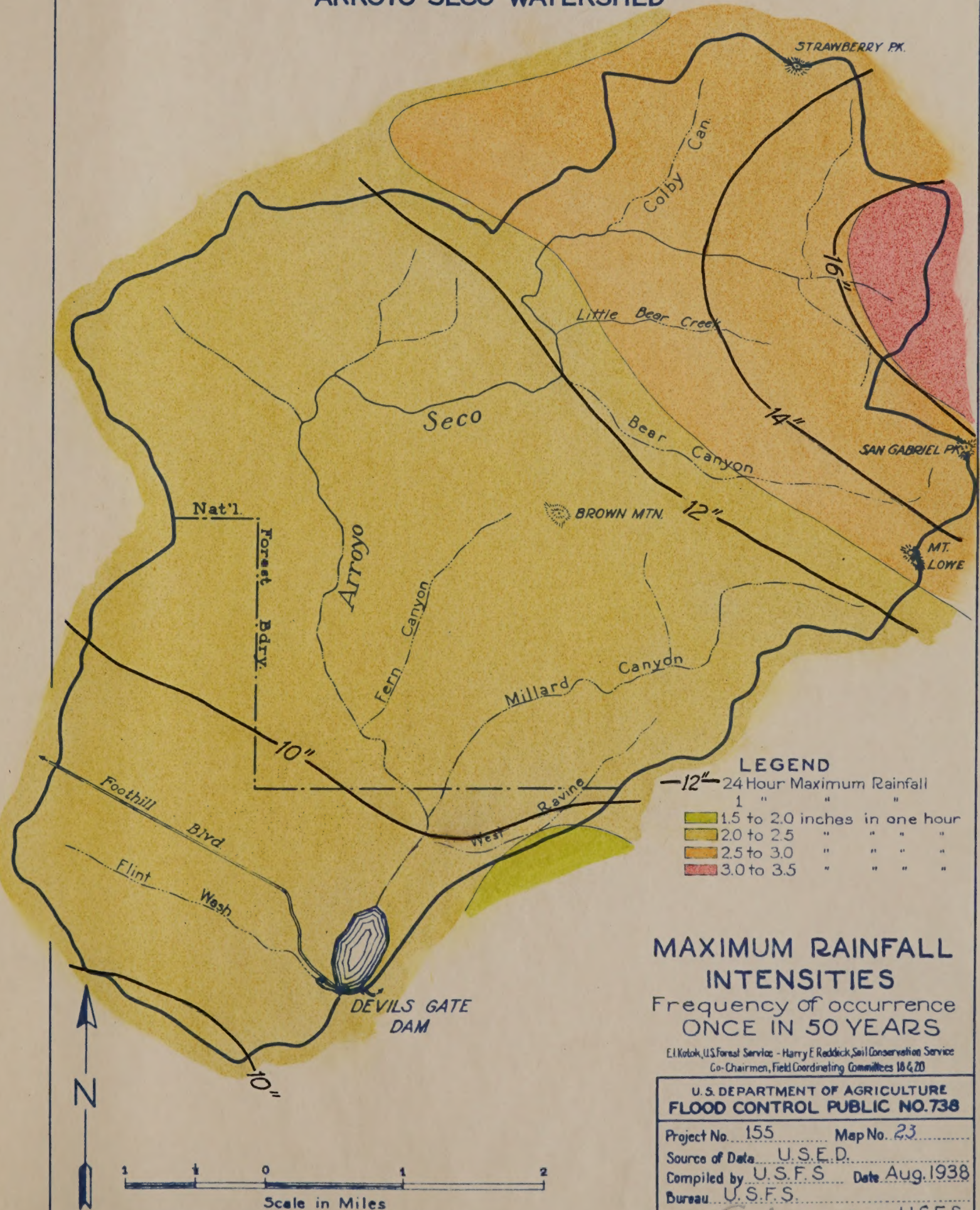
LOS ANGELES RIVER & TRIBUTARIES No. 155

ARROYO SECO WATERSHED



LOS ANGELES RIVER & TRIBUTARIES No. 155

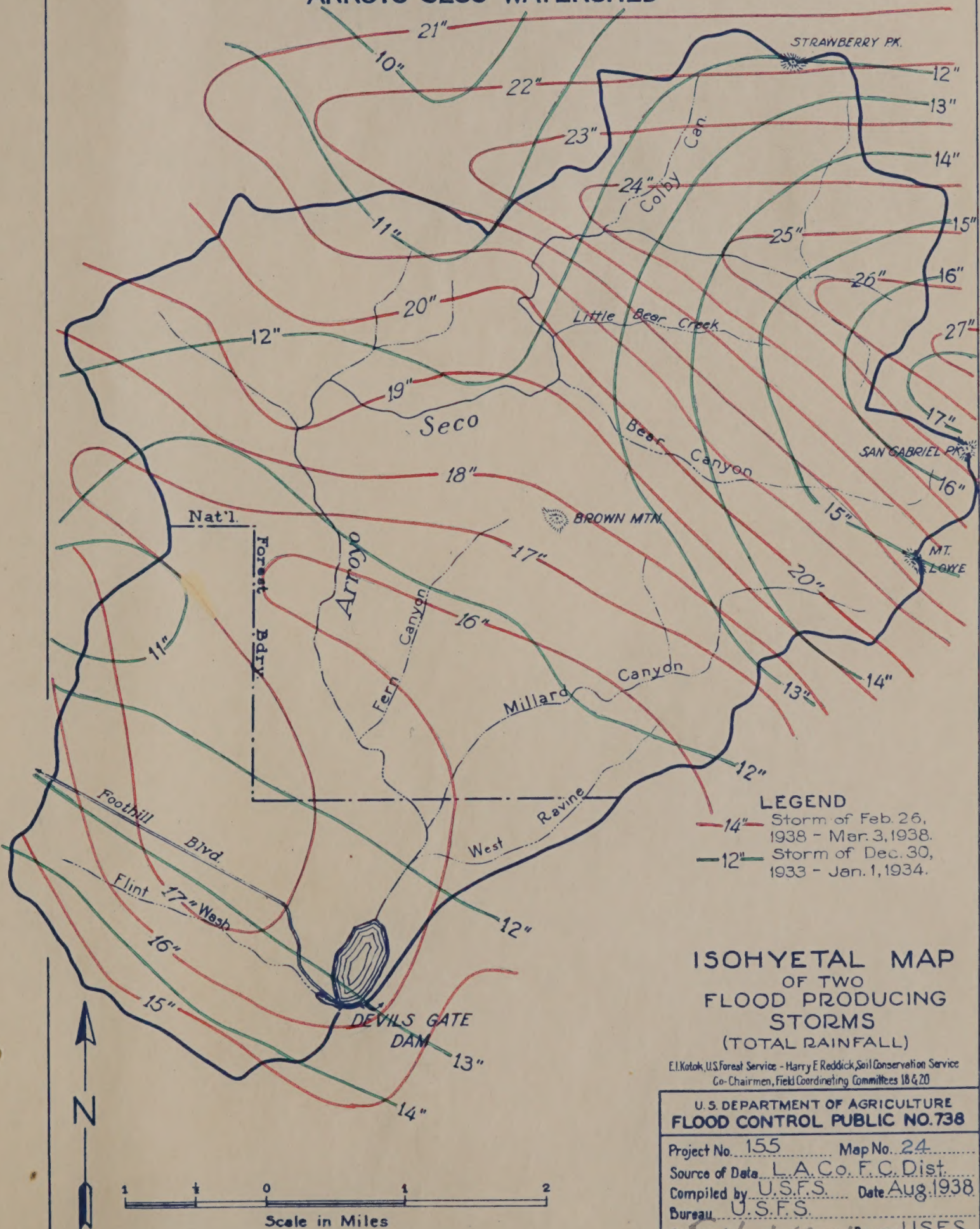
ARROYO SECO WATERSHED

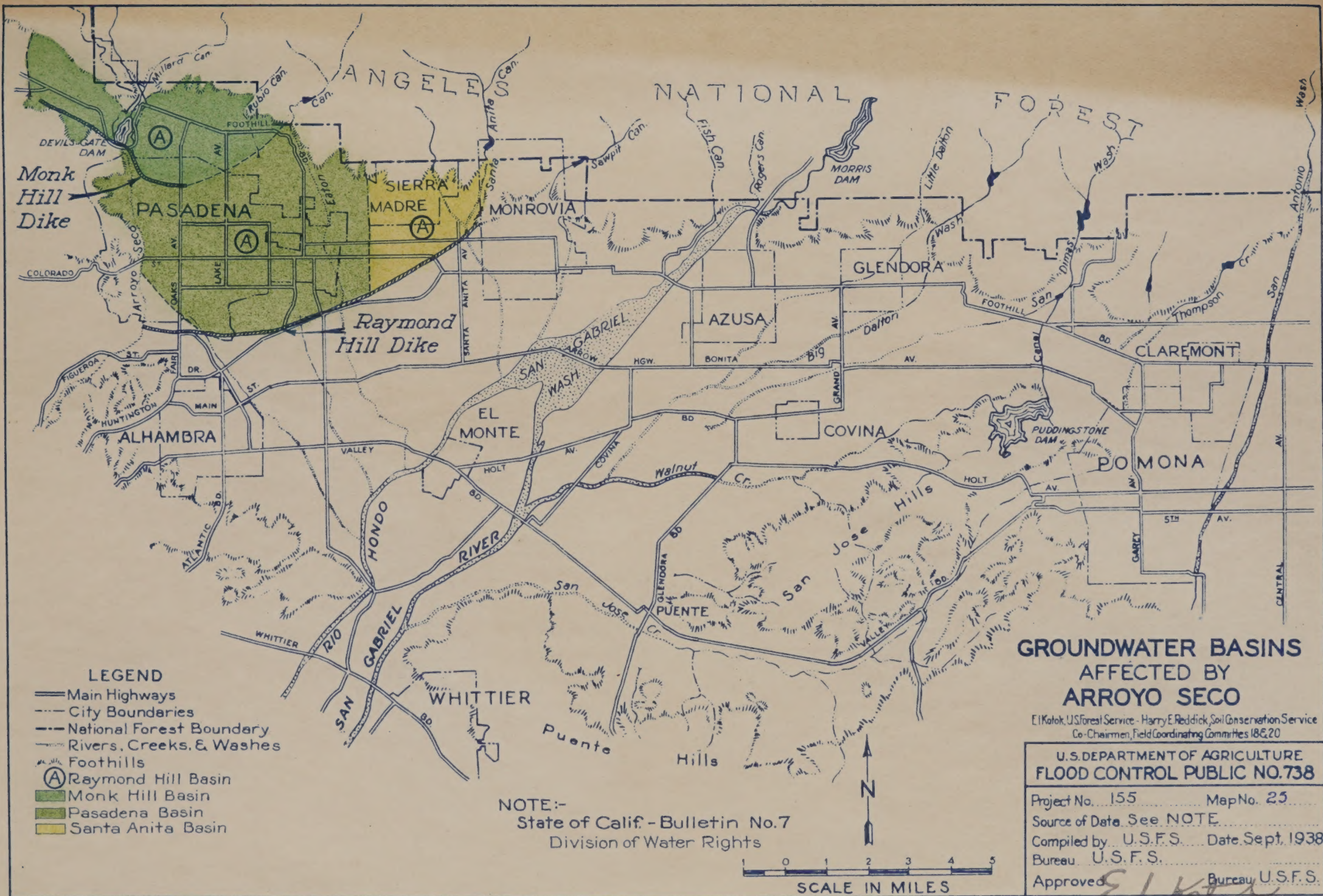




LOS ANGELES RIVER & TRIBUTARIES No. 155

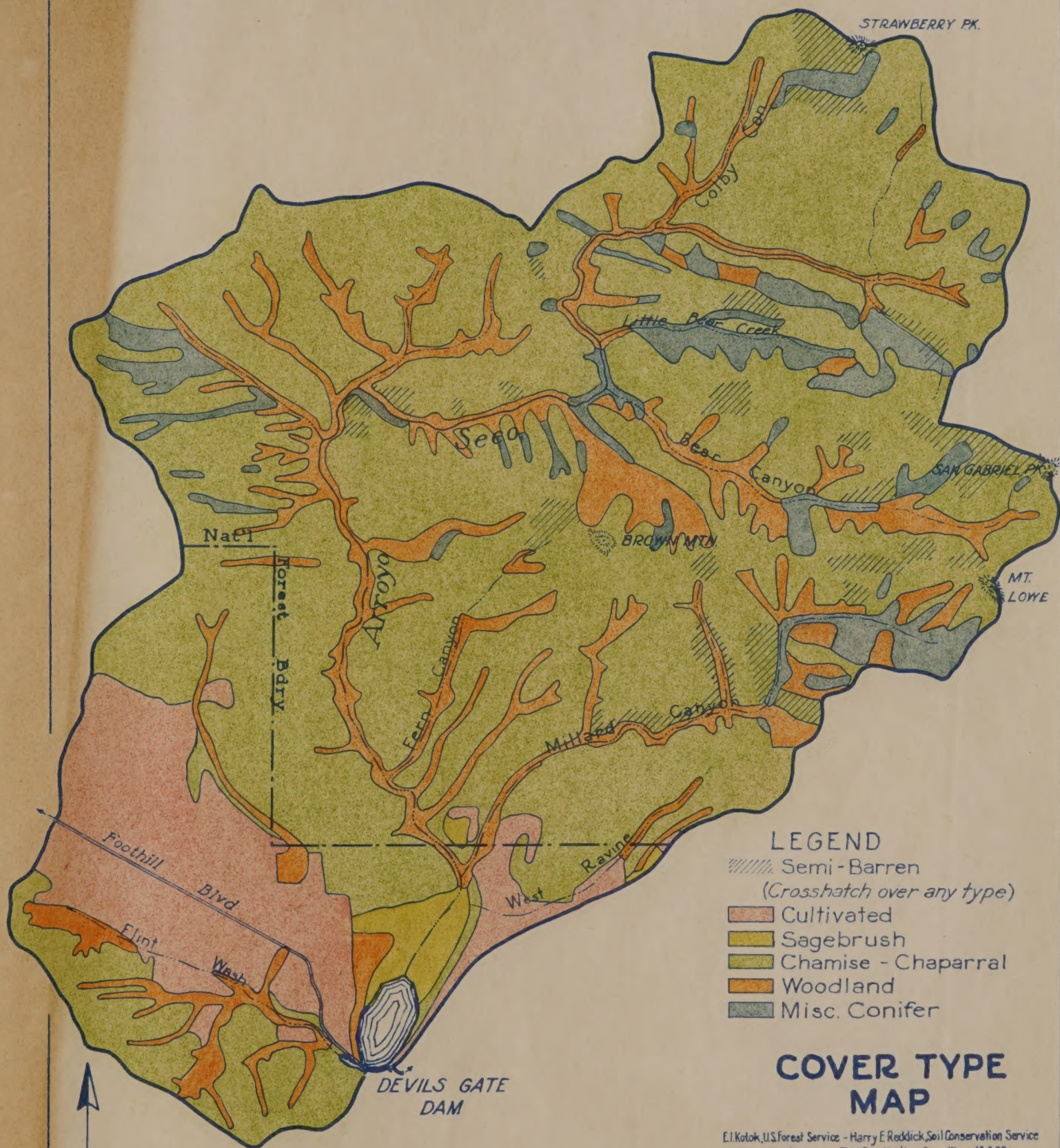
ARROYO SECO WATERSHED





LOS ANGELES RIVER & TRIBUTARIES No. 155

ARROYO SECO WATERSHED



LEGEND

- /// Semi-Barren
(Crosshatch over any type)
- Cultivated
- Sagebrush
- Chamise - Chaparral
- Woodland
- Misc. Conifer

COVER TYPE MAP

E.I. Kotok, U.S. Forest Service - Harry E. Reddick, Soil Conservation Service
Co-Chairmen, Field Coordinating Committees 18 & 20

U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738

Project No. 155 Map No. 26
Source of Data U.S.F.S.
Compiled by U.S.F.S. Date Aug. 1938
Bureau U.S.F.S.
Approved E.I. Kotok Bureau U.S.F.S.

AWL

BASE-U.S.G.S. 1:62,500 SCALE

LOS ANGELES RIVER & TRIBUTARIES No. 155

ARROYO SECO WATERSHED



FIRE HISTORY MAP

E.L. Kolok, U.S. Forest Service - Harry E. Reddick, Soil Conservation Service
Co-Chairmen, Field Coordinating Committees 18 & 20

U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738

Project No. 155 Map No. 27
Source of Data U.S.F.S.
Compiled by U.S.F.S. Date 7/28/38
Bureau U.S.F.S.
Approved *E.L. Kolok* Bureau U.S.F.S.
AWL



Scale in Miles

BASE - U.S.G.S. 1:62,500 SCALE

TYPICAL CANYON PROFILE
SHOWING
PROPOSED CONTROL MEASURES

STA. L-0+00 L-94+00

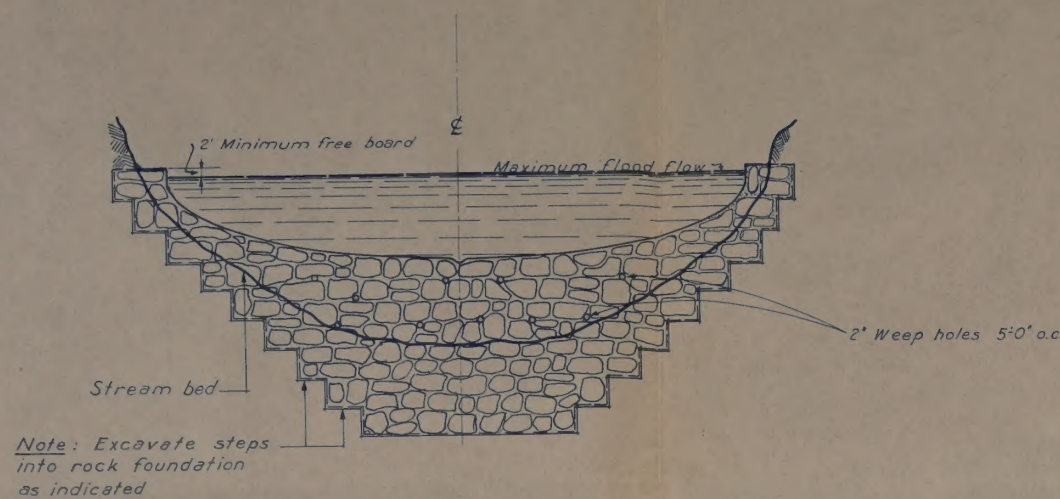
SCALES

VERTICAL 1 INCH=80 FT.
HORIZONTAL 1 INCH=80 FT.

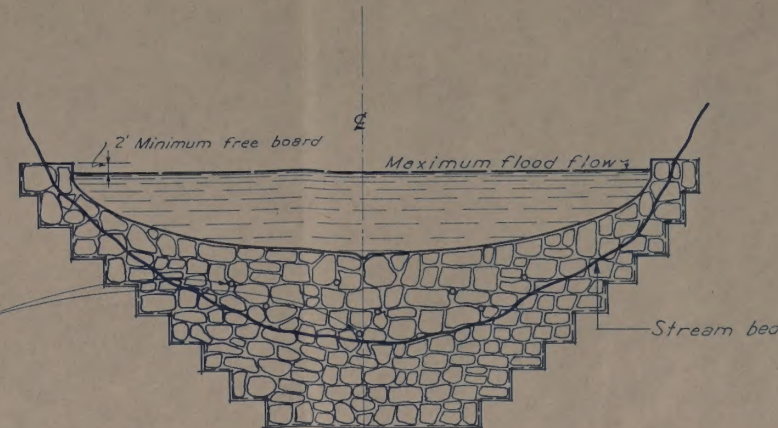
LEGEND

- RETAINING WALLS
R= RIGHT
L= LEFT
- CHANNEL CLEARING
- CHANNEL CONTROL BARRIER

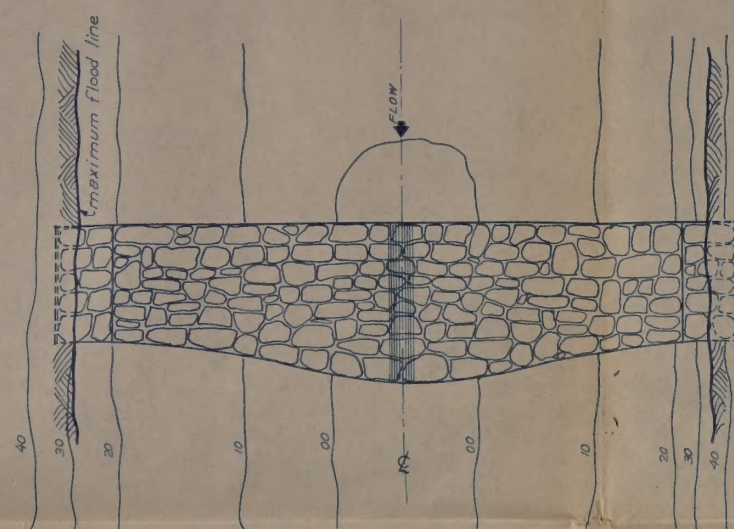




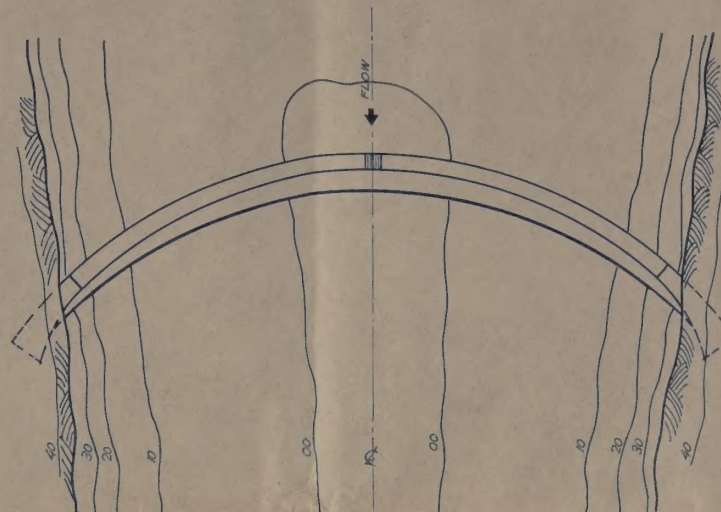
ELEVATION



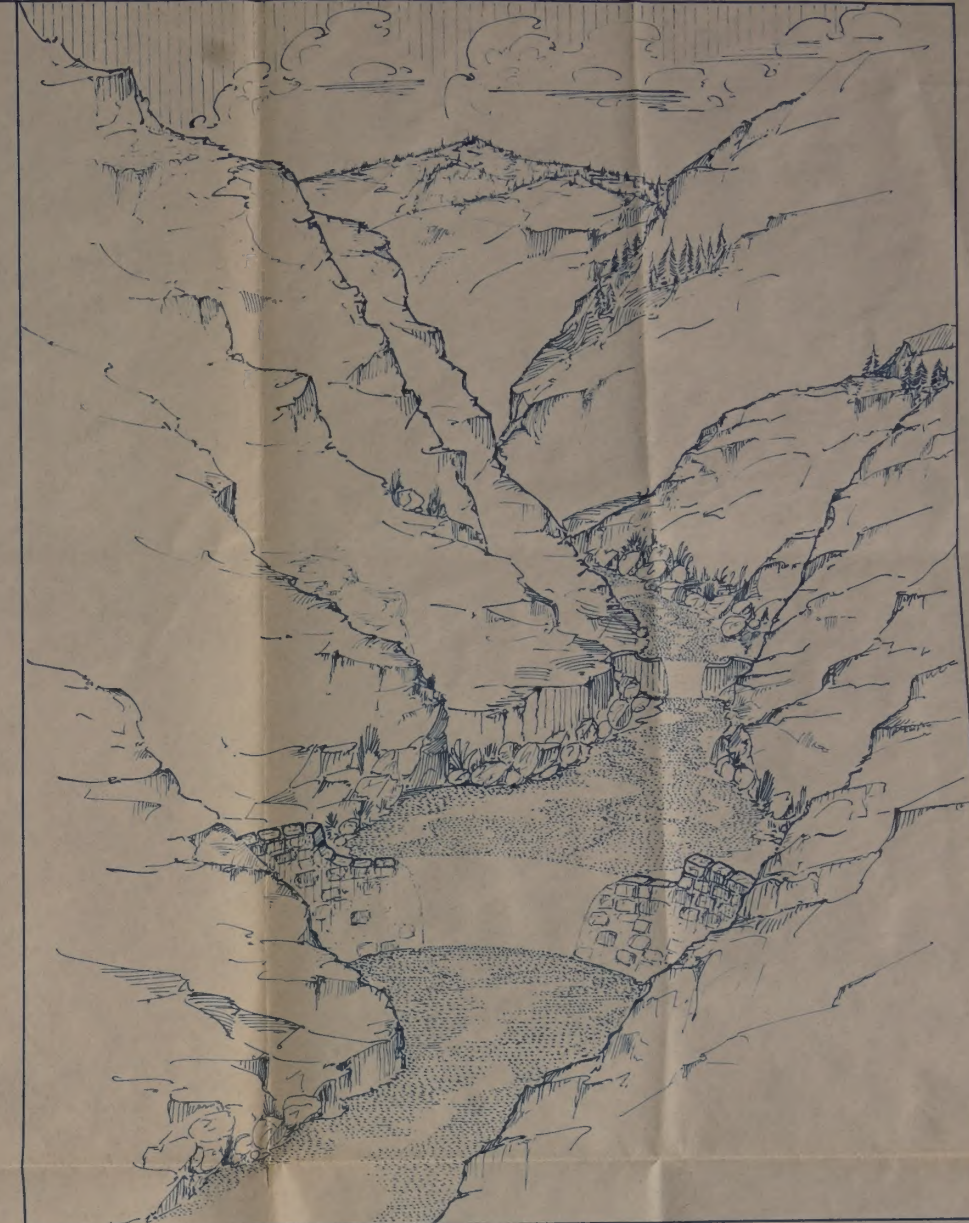
ELEVATION



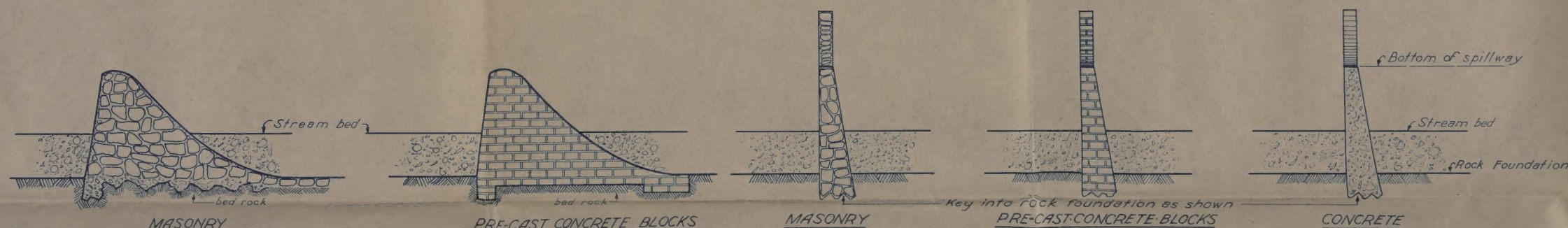
PLAN



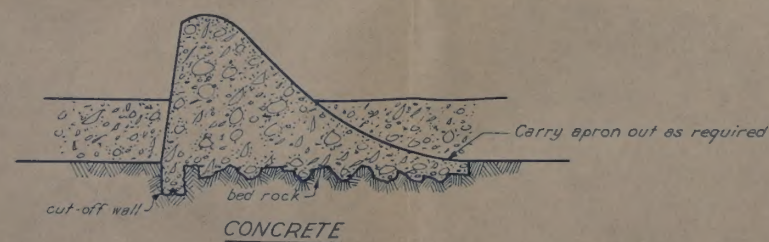
PLAN



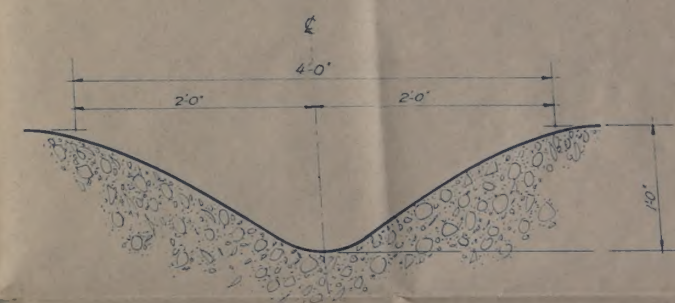
SKETCH SHOWING TYPICAL INSTALLATION
ARCH TYPE BARRIER



SECTION AT ϕ
ARCH TYPE BARRIER



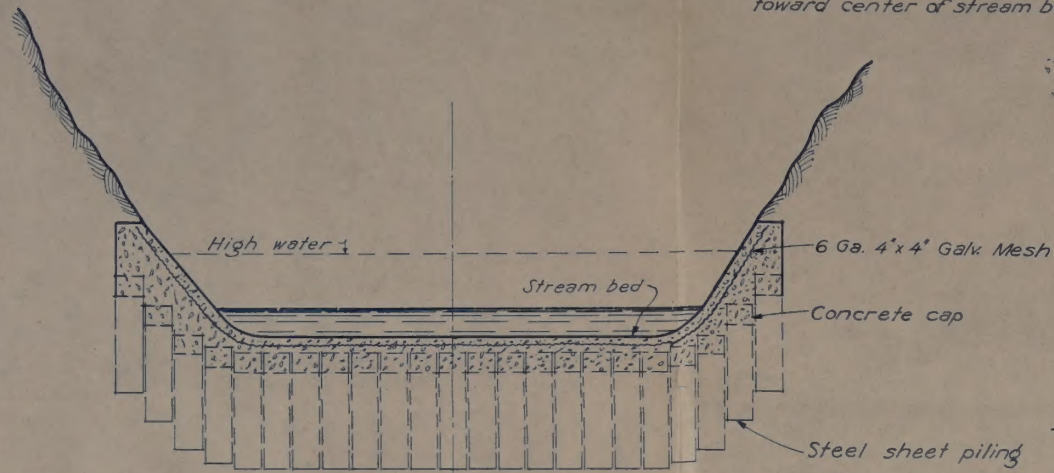
SECTION AT ϕ
GRAVITY TYPE BARRIER



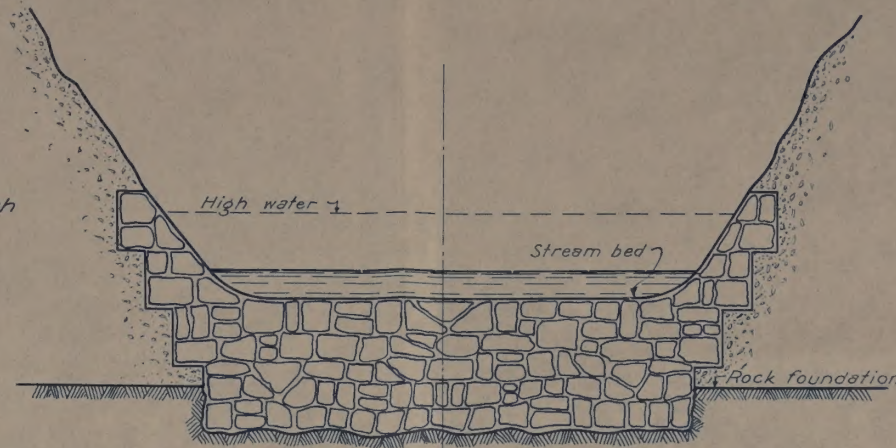
DETAIL OF CREST
AT ϕ

U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738
STANDARD STRUCTURES
CHANNEL CONTROL BARRIERS

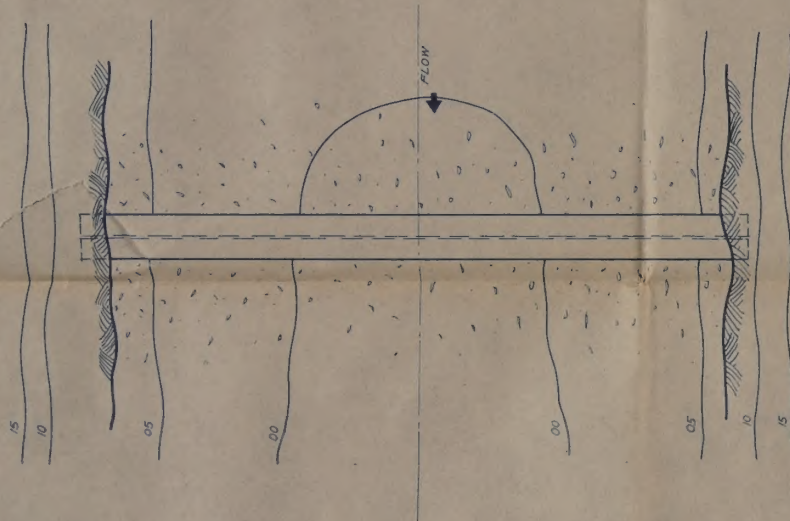
Note: It is desirable to slope paving toward center of stream bed



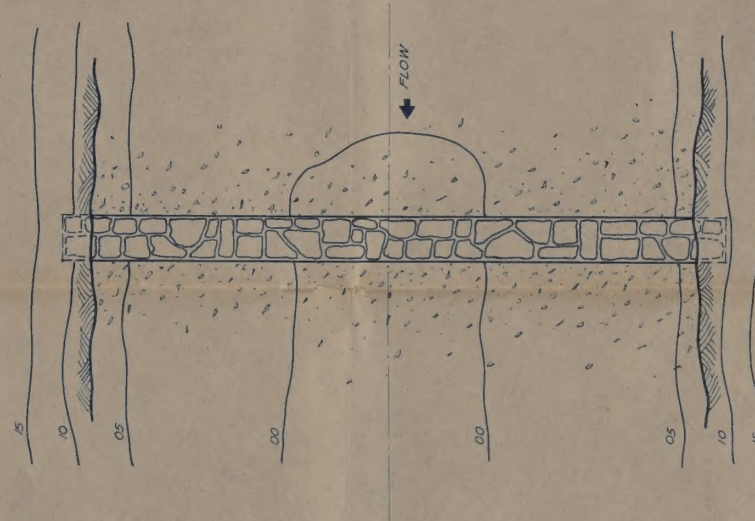
ELEVATION



ELEVATION



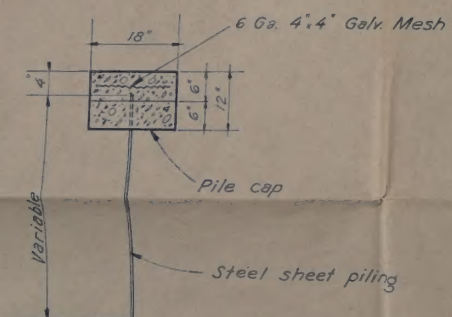
PLAN



PLAN

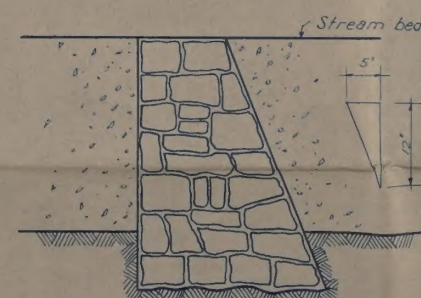


SKETCH SHOWING TYPICAL INSTALLATION

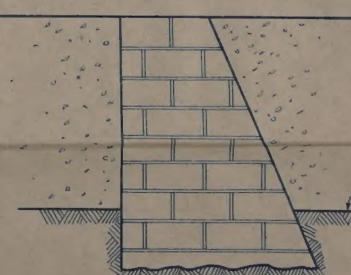


SECTION AT C

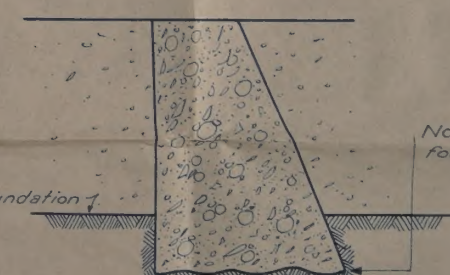
SHEET PILING TYPE SILL



MASONRY



PRE-CAST CONCRETE BLOCKS



CONCRETE

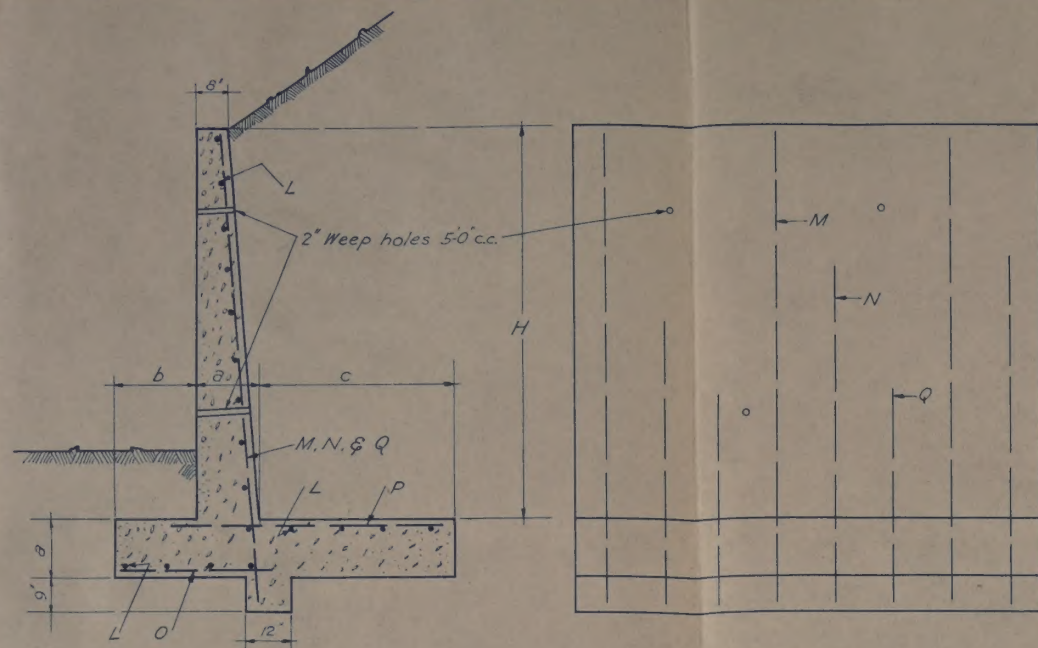
Note - Key into rock foundation as indicated

SECTIONS AT C

GRAVITY TYPE SILL

U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738

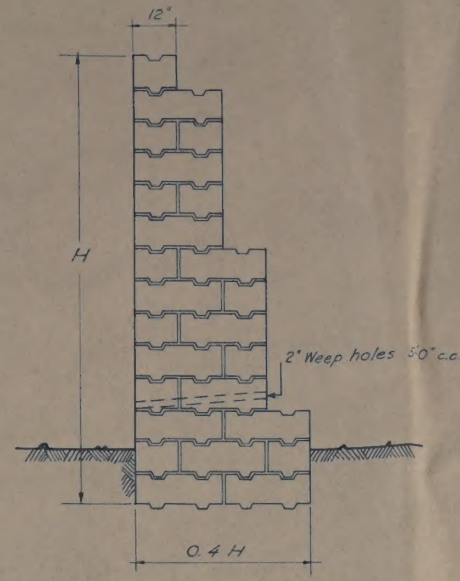
STANDARD STRUCTURES
CHANNEL CONTROL SILLS



SECTION

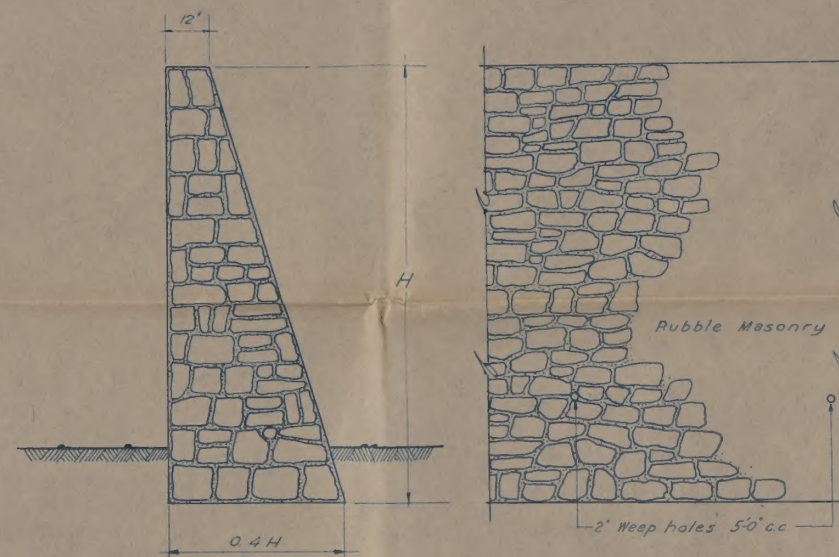
CONCRETE WALL

ELEVATION



SECTION

PRE-CAST CONCRETE BLOCKS



SECTION

MASONRY WALL

ELEVATION

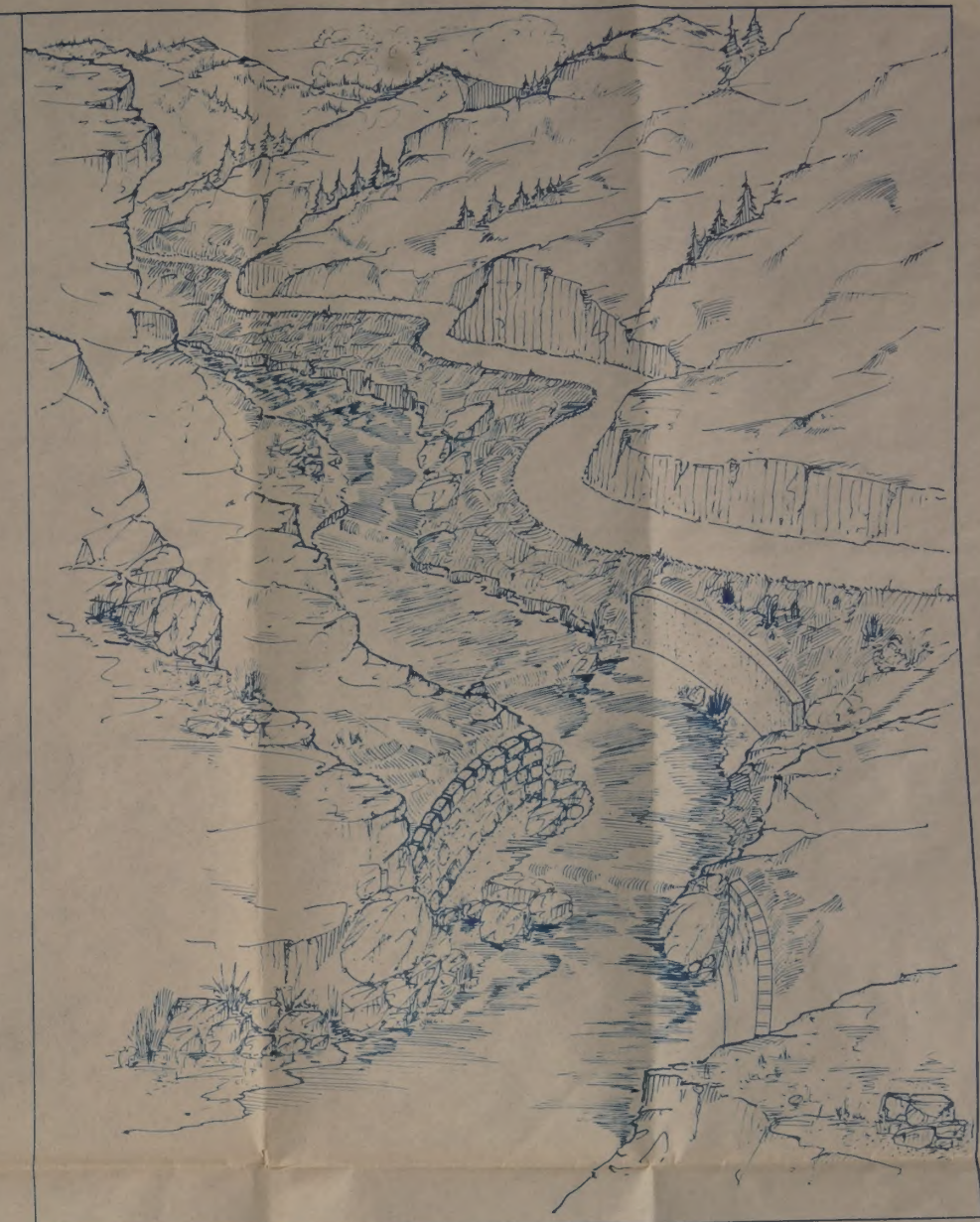
REINFORCEMENT

Height of Wall in feet	M Bars			N Bars			Q Bars			O Bars			P Bars			L Bars			Pounds per ft. Length of Wall
	Size	Spacing in inches	Length	Size	Spacing in inches	Length	Size	Spacing in inches	Length	Size	Spacing in inches	Length	Size	Spacing in inches	Length	No.	Size	Spacing in inches	
7	3/4"	14	8'6"	3/4"	14	4'0"				3/4"	9 1/2	2'6"	3/4"	11	4'0"	13	3/4"	12	18.9
8	3/4"	17	9'9"	3/4"	17	4'6"				3/4"	8	2'9"	3/4"	8	4'9"	14	3/4"	12	24.5
9	3/4"	13	10'9"	3/4"	13	5'0"				3/4"	12	3'3"	3/4"	10	5'9"	17	3/4"	12	33.8
10	3/4"	16	12'6"	3/4"	16	6'0"				3/4"	8 1/2	3'6"	3/4"	8 1/2	6'3"	19	3/4"	12	43.3
11	3/4"	19 1/2	13'6"	3/4"	19 1/2	7'6"	3/4"	10 1/2	5'6"	3/4"	12	4'0"	3/4"	8 1/2	6'3"	21	3/4"	12	49.5
12	3/4"	16 1/2	14'9"	3/4"	16 1/2	7'9"	3/4"	18 1/2	5'9"	3/4"	9	4'3"	3/4"	11	7'3"	23	3/4"	12	61.9
13	3/4"	19 1/2	15'9"	3/4"	19 1/2	8'6"	3/4"	20 1/2	6'3"	3/4"	8	4'6"	3/4"	8	7'9"	24	3/4"	12	85.0
14	3/4"	16 1/2	17'0"	3/4"	16 1/2	9'0"	3/4"	16 1/2	6'6"	3/4"	5 1/2	4'9"	3/4"	7 1/2	7'9"	25	3/4"	12	100.3
15	1"	18	18'0"	1"	18	9'6"	1"	18	6'9"	3/4"	8	5'3"	3/4"	9	4'9"	28	3/4"	12	122.4
16	1"	16 1/2	19'3"	1"	16 1/2	10'0"	1"	16 1/2	7'0"	3/4"	7	5'6"	3/4"	8	9'0"	30	3/4"	12	139.2
17	1 1/8"	18	20'3"	1 1/8"	18	10'6"	1 1/8"	18	7'6"	3/4"	6	5'9"	3/4"	7	9'6"	31	3/4"	12	164.0
18	1 1/8"	16 1/2	21'6"	1 1/8"	16 1/2	11'0"	1 1/8"	16 1/2	7'9"	3/4"	8	6'3"	3/4"	8 1/2	10'0"	34	3/4"	12	185.8
19	1 1/4"	18	22'6"	1 1/4"	18	11'9"	1 1/4"	18	8'3"	3/4"	6 1/2	6'6"	3/4"	8	10'6"	35	3/4"	12	215.7
20	1 1/4"	16 1/2	23'9"	1 1/4"	16 1/2	12'3"	1 1/4"	16 1/2	8'6"	3/4"	6	7'0"	3/4"	7 1/2	10'6"	37	3/4"	12	241.0

CANTILEVER RETAINING WALL

Surface of earth surcharged
Angle of repose 33°

Weight of earth 100# per cu. ft.
f_s = 16000# per sq. in.
f_c = 650# per sq. in.
n = 15
Hooks are required for M, N, & Q bars for walls over 9 ft. in height



SKETCH SHOWING TYPICAL INSTALLATION

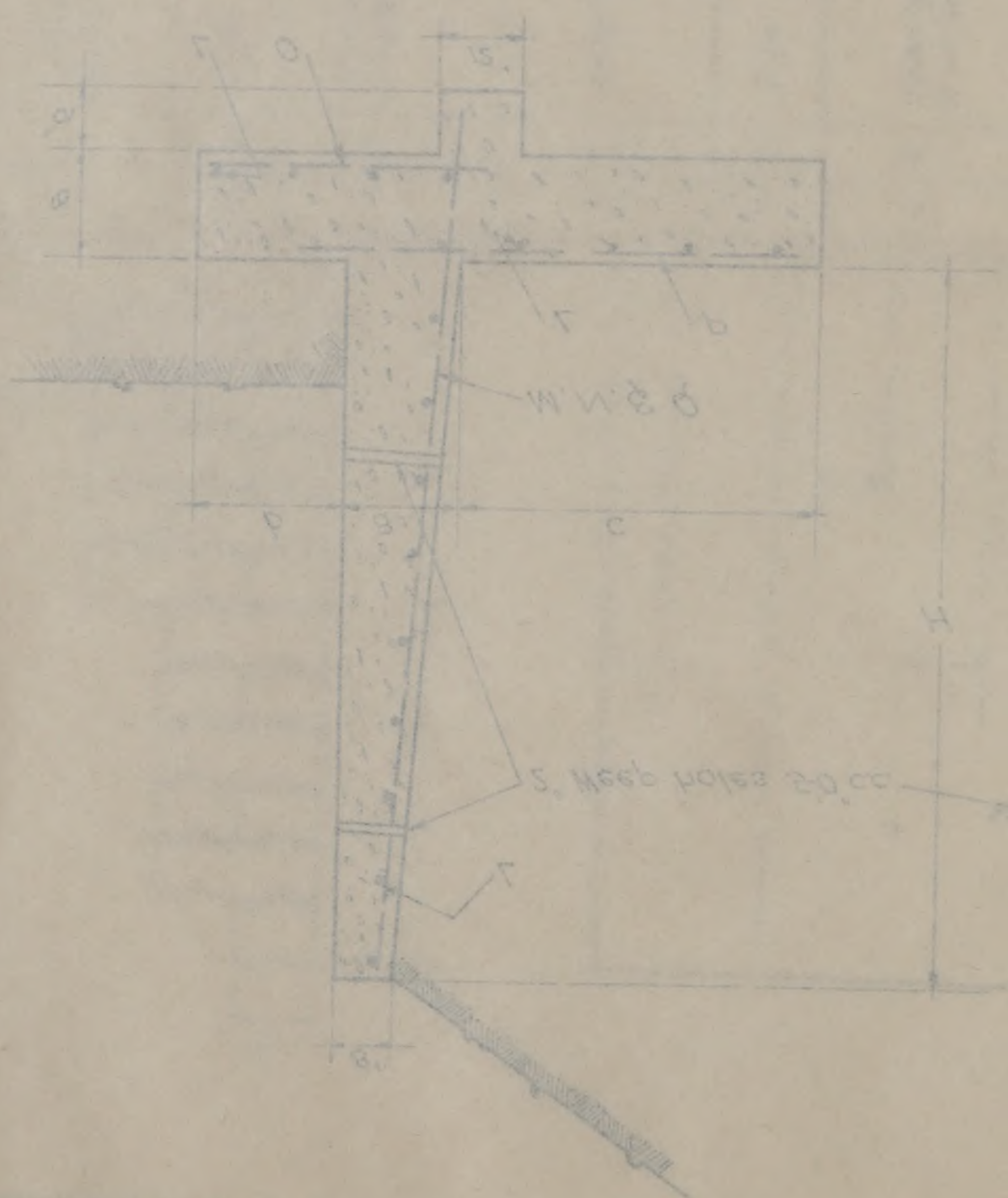
CONCRETE

Height of Wall in feet	a	b	c	Soil Pressure at Toe	Soil Pressure at Heel	Concrete per ft. Length of Wall
Feet				Lbs. per sq. ft.	Lbs. per sq. ft.	cu. ft.
7	1'-0"	1'-4"	2'-8"	2230	270	11.55
8	1'-1 1/2"	1'-6"	3'-7 1/2"	2370	510	14.79
9	1'-3"	1'-8"	4'-1"	2700	540	18.12
10	1'-4 1/2"	1'-10"	4'-6 1/2"	3020	580	21.61
11	1'-6"	2'-0"	4'-8"	3300	640	24.90
12	1'-7 1/2"	2'-3"	5'-1 1/2"	3730	550	29.12
13	1'-9"	2'-5"	5'-7"	4060	560	33.50
14	1'-10 1/2"	2'-8"	5'-9 1/2"	4340	620	37.80
15	2'-0"	2'-10"	6'-2"	4770	550	42.75
16	2'-1 1/2"	3'-0"	6'-5 1/2"	5170	510	47.50
17	2'-3"	3'-2"	6'-11"	5400	550	53.28
18	2'-4 1/2"	3'-4"	7'-2 1/2"	5930	470	58.85
19	2'-6"	3'-8"	7'-6"	6090	550	65.05
20	2'-7 1/2"	4'-0"	7'-8 1/2"	6350	630	71.30

U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738
STANDARD STRUCTURES
TRAINING & RETAINING WALLS

CONCRETE

SECTION



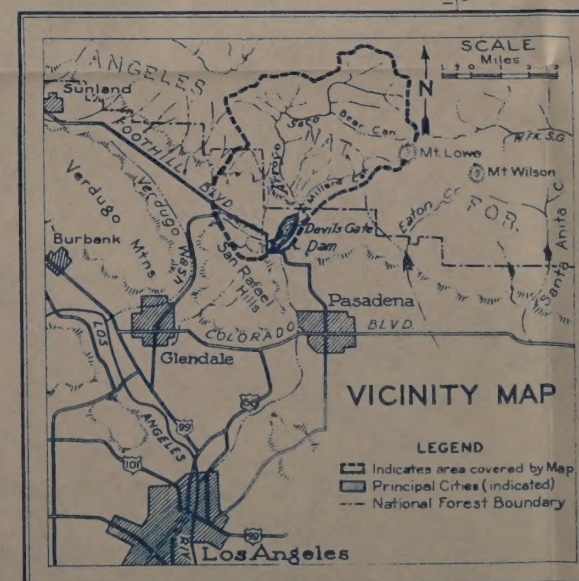
LOS ANGELES RIVER & TRIBUTARIES No. 155

ARROYO SECO WATERSHED

LANDSLIDE CONTROL MAP



- LEGEND**
- Landslide Not classified
 - + Landslide to be planted
 - ⊥ Landslide requiring toe wall
 - ⊥ Landslide requiring planting & toe wall
 - ▨ Semi-barren areas
 - Boundary of Critical Sub drainage areas



U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738

Project No. 155 Map No. 34

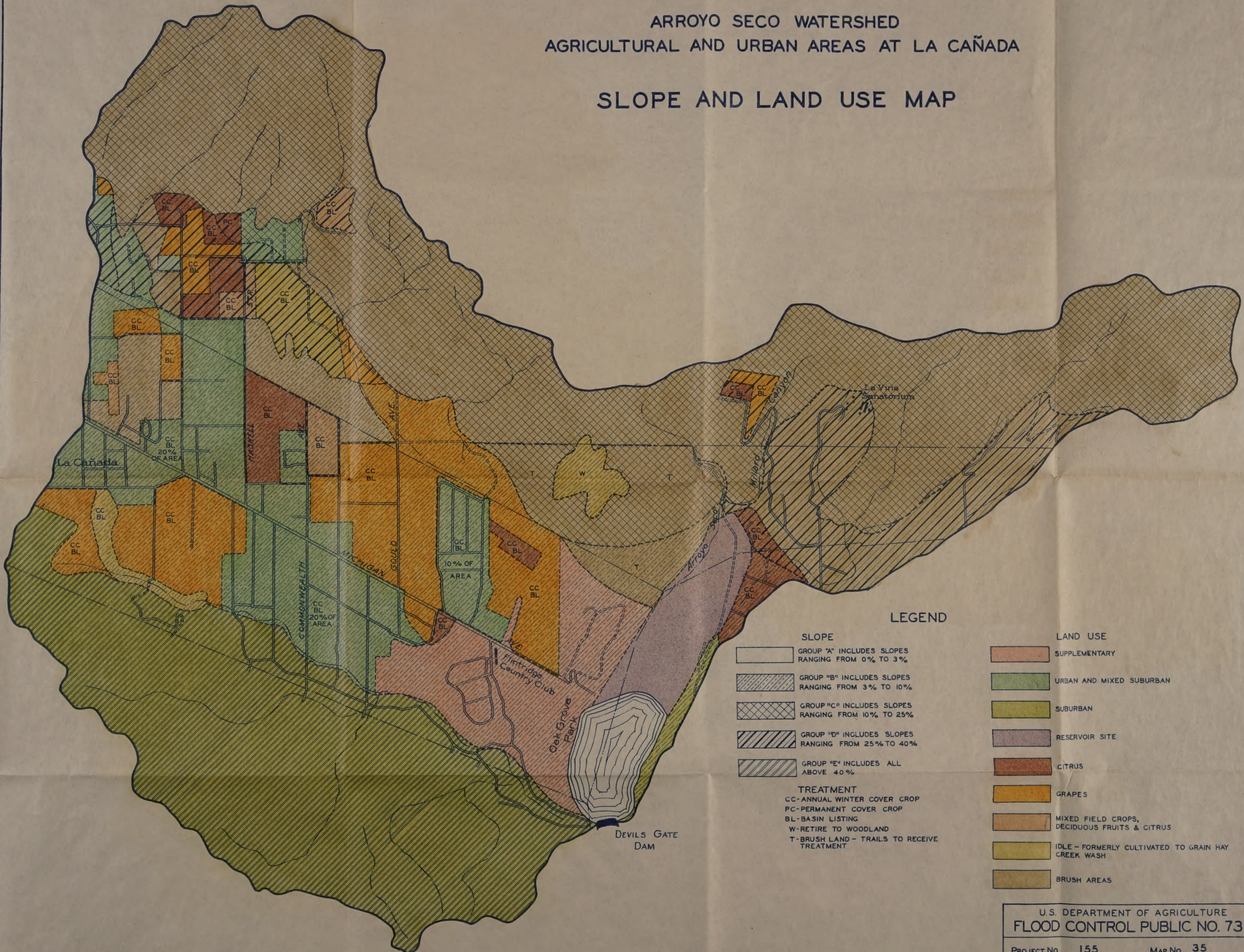
Source of Data Field Survey - U.S.F.S.
Compiled by U.S.F.S. Date July 1938

Bureau U.S.F.S.
Approved *E. I. Koto* Bureau U.S.F.S.

LOS ANGELES RIVER & TRIBUTARIES No. 155

ARROYO SECO WATERSHED AGRICULTURAL AND URBAN AREAS AT LA CAÑADA

SLOPE AND LAND USE MAP



LEGEND

SLOPE

- GROUP "A" INCLUDES SLOPES RANGING FROM 0% TO 3%
- GROUP "B" INCLUDES SLOPES RANGING FROM 3% TO 10%
- GROUP "C" INCLUDES SLOPES RANGING FROM 10% TO 25%
- GROUP "D" INCLUDES SLOPES RANGING FROM 25% TO 40%
- GROUP "E" INCLUDES ALL ABOVE 40%

TREATMENT

- CC-ANNUAL WINTER COVER CROP
- PC-PERMANENT COVER CROP
- BL-BASIN LISTING
- W-RETIRE TO WOODLAND
- T-BRUSH LAND - TRAILS TO RECEIVE TREATMENT

LAND USE

- SUPPLEMENTARY
- URBAN AND MIXED SUBURBAN
- SUBURBAN
- RESERVOIR SITE
- CITRUS
- GRAPES
- MIXED FIELD CROPS, DECIDUOUS FRUITS & CITRUS
- IDLE - FORMERLY CULTIVATED TO GRAIN HAY CREEK WASH
- BRUSH AREAS

U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738

PROJECT No. 155 MAP No. 35
SOURCE OF DATA SCS. - FIELD SURVEY
COMPILED BY U.S.F.S. DATE NOV. 7, 1938
BUREAU U.S.F.S.
APPROVED BUREAU U.S.F.S.



LOS ANGELES

LOS ANGELES

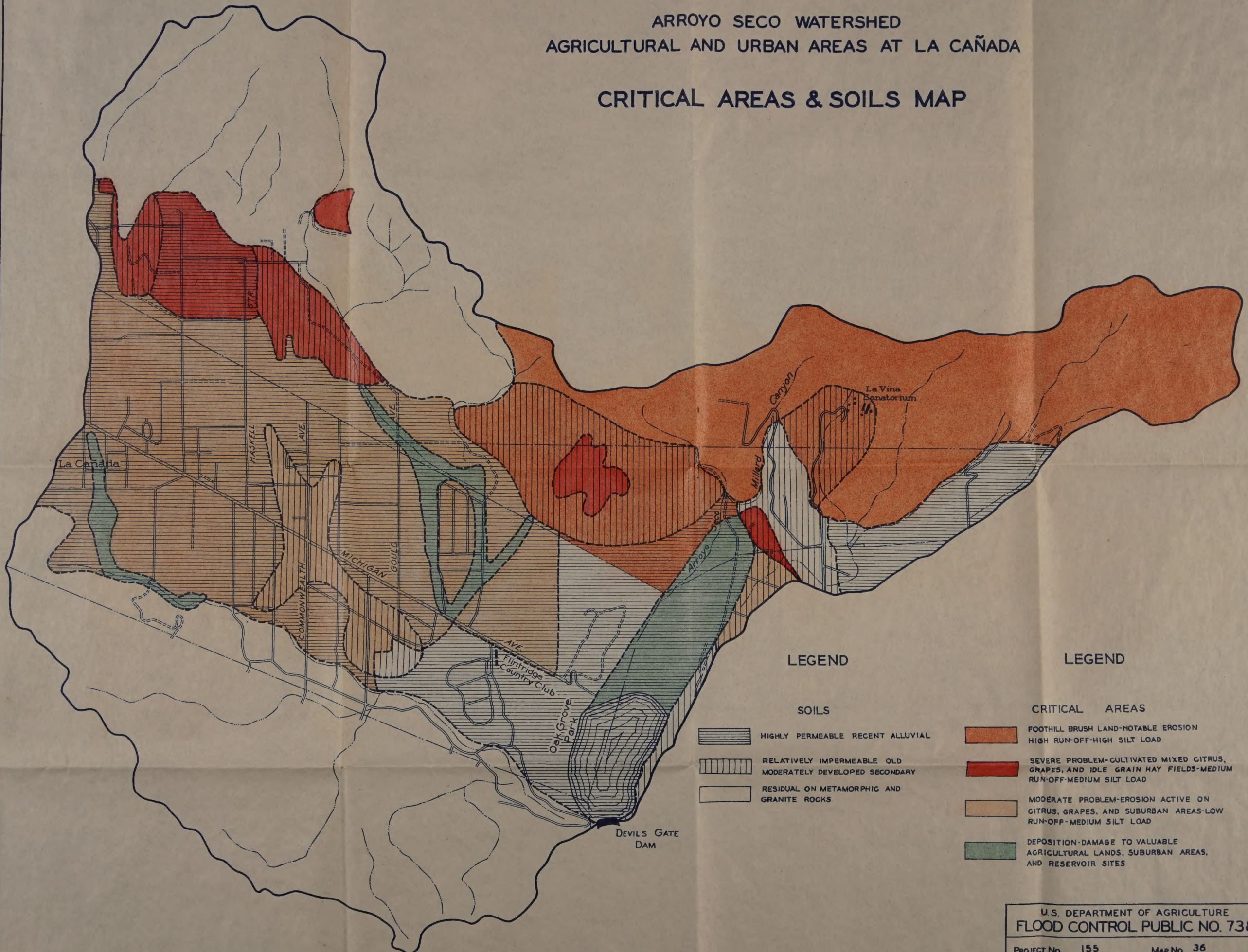
LOS ANGELES

LOS ANGELES

LOS ANGELES RIVER & TRIBUTARIES No. 155

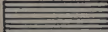
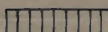
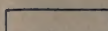
ARROYO SECO WATERSHED AGRICULTURAL AND URBAN AREAS AT LA CAÑADA

CRITICAL AREAS & SOILS MAP



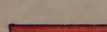
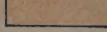
LEGEND

SOILS

-  HIGHLY PERMEABLE RECENT ALLUVIAL
-  RELATIVELY IMPERMEABLE OLD MODERATELY DEVELOPED SECONDARY
-  RESIDUAL ON METAMORPHIC AND GRANITE ROCKS

LEGEND

CRITICAL AREAS

-  FOOTHILL BRUSH LAND-NOTABLE EROSION HIGH RUN-OFF-HIGH SILT LOAD
-  SEVERE PROBLEM-CULTIVATED MIXED CITRUS, GRAPES, AND IDLE GRAIN HAY FIELDS-MEDIUM RUN-OFF-MEDIUM SILT LOAD
-  MODERATE PROBLEM-EROSION ACTIVE ON CITRUS, GRAPES, AND SUBURBAN AREAS-LOW RUN-OFF-MEDIUM SILT LOAD
-  DEPOSITION-DAMAGE TO VALUABLE AGRICULTURAL LANDS, SUBURBAN AREAS, AND RESERVOIR SITES

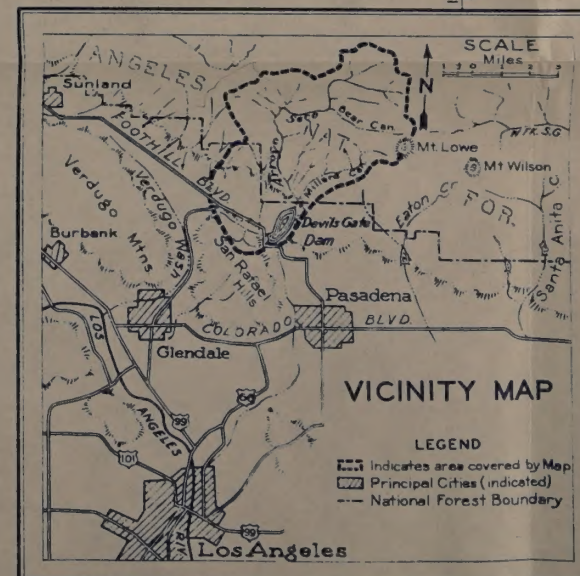
U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738

PROJECT No. 155 MAP No. 36
SOURCE OF DATA SCS FIELD SURVEY
COMPILED BY U.S.F.S. DATE NOV. 7, 1938
BUREAU U.S.F.S.
APPROVED *E. J. Ketchum* BUREAU U.S.F.S.

LOS ANGELES RIVER & TRIBUTARIES No. 155

ARROYO SECO WATERSHED

EXISTING AND PROPOSED FIRE PROTECTION PROJECTS



- LEGEND**
- Watershed Boundary
 - Angeles National Forest Boundary
 - Main Motor Highway
 - Private Land within National Forest
 - Existing Truck Trail
 - Trail
 - Firebreak
 - Water System
 - Telephone Line
 - Proposed Truck Trail
 - Trail

U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738

Project No. 155 Map No. 38

Source of Data U.S.F.S.
Compiled by U.S.F.S. Date Aug 1938

Bureau U.S.F.S.
Approved *E. I. Ketchum* Bureau U.S.F.S.

LOS ANGELES RIVER & TRIBUTARIES No. 155

ARROYO SECO WATERSHED AGRICULTURAL AND URBAN AREAS AT LA CAÑADA

PROPOSED FLOOD CONTROL MEASURES



LEGEND

EXISTING	PROPOSED	
=====	=====	ROAD DRAINAGE DITCH - UNLINED
=====	=====	LINED DRAINAGE DITCH
=====	=====	MASONRY STABILIZING DAM
=====	=====	EARTH FILL DAM OR RETENTION BASIN
=====	=====	PIPE OR CULVERT
=====	=====	TERRACE DIKES
=====	=====	TERRACE DIKE OUTLET
=====	=====	PAVED ROAD USED AS DRAIN

NOTE: - Figures on Drops indicate height of breast wall.

U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738

PROJECT No. 155 MAP No. 37

SOURCE OF DATA S.C.S. FIELD SURVEY

COMPILED BY U.S.F.S. DATE NOV. 8, 1938

BUREAU U.S.F.S.

APPROVED E.I. Ketchum BUREAU U.S.F.S.

PROJECTS FIRE PROTECTION AND PROPOSED

18
345

LOS ANGELES RIVER & TRIBUTARIES No. 155

ARROYO SECO WATERSHED

ROAD EROSION
MAP



- LEGEND
- Watershed Boundary
 - Angeles National Forest Boundary
 - Main Motor Highway
 - Private Land within National Forest
 - Truck Trail
 - Roadslopes to be treated
 - Culvert
 - Spillway
 - Retaining or Toe Wall

U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738

Project No. 155 Map No. 28

Source of Data Field Survey - U.S.F.S.
Compiled by U.S.F.S. Date July 1938

Bureau U.S.F.S.
Approved *E. J. Ketchum* Bureau U.S.F.S.

Made by AGCO PRODUCTS, INC.

NO. BF 250

ACCOPRESS BINDER

